Royal Commission on Renewing
and Strengthening Our Place in Canada

What Does Newfoundland and Labrador Need to Know About the Knowledge-Based Economy to Strengthen Its Place in Canada?

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The views expressed herein are solely those of the author and do not necessarily reflect those of the Royal Commission on Renewing and Strengthening Our Place in Canada.

Abstract

This paper reviews the relevant literature, assesses available indicators of knowledge capacity and performance and provides an evaluation of the role that the knowledge economy can realistically play in strengthening Newfoundland and Labrador's position in Canada. We find that knowledge, research and development and innovation activities have significant roles to play in enhancing Newfoundland and Labrador's productivity, competitiveness and economic growth. However, provincial indicators of knowledge capacity and performance are not encouraging. A series of recommendations are suggested as to how the Royal Commission might optimize the role of the knowledge economy in strengthening Newfoundland and Labrador's position in Canada.

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Introduction

> *Globalization and the knowledge/information revolution are signaling the advent of a new socio-economic order with profound and pervasive implications for citizens, governments, markets and, therefore, public policy …to succeed in this new global order, Canada and Canadians must make the transition from a resource- and physical-capital-based economy and society to human-capital-based economy and society.*
>
> *Introduction to A State of Minds*
> *Tom Courchene, 2001*

Given the potential for the knowledge economy to transform social and economic interactions, it is important to consider how knowledge could be exploited to strengthen Newfoundland and Labrador's position in Canada. Therefore, this study investigates ways in which the knowledge-economy could facilitate the *Royal Commission on Renewing and Strengthening Our Place in Canada* in meeting its mandate.

The literature associated with the knowledge economy is so broad and comprehensive that the best any single study could hope to achieve is a superficial summary of the relevant information contained therein. Consequently, this study then focuses on some of the more important economic issues, leaving it to other researchers to address issues that are beyond our areas of expertise. This research and analysis paper reviews the relevant literature, assesses Newfoundland and Labrador's knowledge capacity and performance indicators and combines the informational content in both to provide guidance to the Royal Commission as to the issues that it should consider.

In addition to the introduction, this paper consists of eight other sections. The contributions of knowledge, research and development and technological progress to economic growth and well-being are evaluated in Section 2. This is followed, in Section 3, by an assessment of the connection between the Internet, advances in information and communication technologies and productivity. Section 4 examines the private and social rates of return on research and development to determine the extent to which these activities contribute to economic growth and/or define a facilitating role for government. Following this is consideration of whether the distinction between tacit and codified knowledge is relevant in assessing the potential role of the knowledge economy in strengthening Newfoundland and Labrador's position within Canada. Tacit knowledge, as explained in Section 6, helps define the spatial distribution of economic activities and has direct implications for the role that the knowledge economy can play in strengthening Newfoundland and Labrador's relative position within Canada. Sections 7 and 8 consider the roles of the education sector and the government, respectively, in a knowledge-based economy. The report concludes with a list of policy recommendations that the Royal Commission might wish to consider in fulfilling its mandate. Finally, three appendices are attached to this report – Appendix A lists innovation activities taking place at Memorial University; Appendix B lists projects funded in Newfoundland and Labrador under the Canadian Foundation for Innovation; and Appendix C lists the projects funded in Newfoundland and Labrador under the Atlantic Innovation Fund.

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Knowledge, R&D, Technological Progress and Economic Growth

> *In the new, global economy of the 21st century prosperity depends on innovation which, in turn depends on the investments that we make in the creativity and talents of our people.*
>
> *Message from Prime Minister Chrétien*
> *Canada's Innovation Strategy, 2002*

> *…in the global knowledge-based economy, research-based innovation is of critical importance in generating high value-added economic activity, increased wealth, economic diversification, well-paying jobs…*
>
> *Expert Panel on the Commercialization of University Research*
> *Government of Canada (1999)*

Consistent with Prime Minister Chrétien's and the Expert Panel's statements, the role that knowledge and innovation play in promoting economic growth and prosperity in today's economy is often taken on face value, requiring little or no additional explanation.[1] Clearly, knowledge is important and, as suggested in *Canada's Innovation Strategy*, new knowledge is becoming relevant more quickly.[2] As well, it is noteworthy to realize that knowledge gets transformed into new products or processes through the process of innovation.

Our review of a subset of the substantial literature pertaining to the role of knowledge and technological progress in economic growth confirms that there is overwhelming empirical evidence corroborating the hypothesis that growth is tied to technological progress.[3] These empirical findings have demonstrated the pivotal role that knowledge and technology play in explaining growth and development and are bolstered by the newer theoretical developments in the economic growth literature.[4]

Globerman (2000) relates technological change to innovation activities. Innovation activities and the corresponding investment in research and development contribute to productivity through new products and processes[5], which, in turn, translate into enhanced competitiveness, elevated economic growth and a higher standard of living than otherwise would be the case[6]. There is a direct connection, albeit not necessarily a linear one, between the level of innovation within an area and the level of prosperity its residents attain.[7] In this context, it is useful initially to list the factors that, according to Globerman (2000), influence the link between technological change and economic growth. These are:

- The education and skill level of the workforce;
- The extent of competition in domestic industries;
- The openness of the domestic economy to foreign trade and foreign direct investment;
- The strength and nature of intellectual property protection;
- The social infrastructure; and,
- Government policies of various types.

Innovation activities, either through new product developments or via the implementation of new or improved processes, are the end of a longer process, a process that starts from the knowledge or science base within a region or country. It is equally important to appreciate that the primary interface between a university and the economy is through its impact on the knowledge base. This impact is manifested via the generation, acquisition and dissemination of knowledge. Specifically, university researchers perform applied and basic research that contribute to the innovation activity of private sector firms; some faculty members collaborate with established private sector firms or start companies that spin off from their own research activities; and, probably most significantly, universities train students who, in turn, create and apply knowledge in the private sector. Last, but not least, the innovation process helps define and expand the knowledge base that can be drawn upon by university researchers in their future work. In other words, an area's knowledge base defines its capacity to develop new ideas or new ways of doing things that ultimately lead to improvements in productivity and economic growth.

Even though a well developed knowledge base may be a necessary ingredient in the innovation process, its presence does not guarantee that successful innovation will generate either elevated productivity levels or improved well-being. Another significant component of the innovation process is the extent to which an area is willing to invest the necessary resources in research and development activities.[8] For an area to reap the productivity benefits that research and development can bring, the research and development activity must be undertaken at a certain level and for a prolonged period.

According to Locke and Lynch (2001), the rates of transformation of research and development into productivity improvements are not uniform across provinces within Canada. This may be explained by the different composition of research and development within each province and the incentives that underlie business research and development versus research and development activities performed at universities. As a result, research and development activities from different sectors may not be perfect substitutes in terms of their impact on productivity and prosperity.

However, research and development investments are the prerequisites for the generation of inventions and patents, which, themselves, are reflective of the amount of an area's created knowledge and the size of its innovative sector. Yet, the development of patents or inventions is of little consequence if they do not eventually get commercialized – that is, turned into a new product or process. Without the development and marketing of new products or processes, an area will not observe any elevated productivity or improvement in its standard of living.

Even after an idea is turned into a new production process or product, the process of innovation does not stop. Once the innovation has been established within the marketplace, it contributes to the existing knowledge base and the innovation cycle begins anew. That is, knowledge is cumulative! Past knowledge and research makes it easier to develop new technological innovations that will contribute to future productivity.[9] The ideas embodied in current research and development initiatives spill over to other industries through their research and development activities. Thus, the acquisition of knowledge expedites and promotes the development of new knowledge, further increasing productivity in an area. This concept is generally reflected in the statement that the social return on research and development exceeds the private return.[10] This implies that research and development activities in one firm or by a particular researcher affect the innovative activities of other firms or researchers, in effect, bestowing a positive externality on them. The difference between the social and private returns to research and development implies that knowledge and information have public good characteristics,[11] which, in turn, provides one of the primary justifications for public sector support of research and development activities.[12] Whether the knowledge created by research and development activity is a ‘pure” public or “quasi” public good is an open question and depends on a number of issues that are dealt with more extensively below.

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ICT, the Internet and Productivity

The ICT sector is at the heart of the Internet revolution…It plays a huge enabling role in the economy as its technologies are used in every industry. It is key to Canada's economic growth, acts as a major engine for new high-quality jobs, leads in the area of innovation and R&D, offers sound infrastructure and a strong technological environment and exists in significant domestic cluster.

Productivity and Innovation:
A Competitive and Prosperous Canada
Report of Standing Committee on Industry
Government of Canada, 2000

Although the knowledge economy involves more than information and communication technologies (ICT) and the Internet, these two features, as illustrated by the above quote, often get singled out for special attention in the literature. For example, an OECD (2000) report credits ICT developments with being "the most important source of technological progress in the 1990s"[13] and it highlights "the strong positive impact of ICT on economic growth and performance" in the United States. This is further corroborated by Blinder (2000), which suggests that IT investment in industry is "positively associated" with productivity growth and that the Internet may explain recent productivity growth in the United States. As well, Litan and Rivlan (2001) conclude that the "increased investment in information technology (IT), coupled with the experience gained in using IT, have played a major role in the recent acceleration of productivity growth" in the United States. This point of view is further reinforced by Globerman (2000) and Visco (2000). In fact, Visco (2000) credits the diffusion and increase in efficiency of ICT with the fact that social return on research and development investment is now starting to exceed the costs. However, Oliner and Sichel (1994) challenge the impact that computers have had on productivity. The basis of their argument rests on the small cost share that computers account for in a typical firm's cost structure. A response to this perspective, provided in Bessen (2001), is that Oliner and Sichel (1994) ignore the enabling function that computers perform in facilitating broader organizational changes that improve productivity. In other words, the productive impact of computers is manifested through its impact on the other inputs in the production function. For example, Brynjolfsson and Hitt (2000) and Black and Lynch (2001) provide evidence that the adoption of ICT within firms is associated with organizational changes, which themselves enhance productivity. Finally, some people have predicted that the advancements in ICT and the Internet would mitigate the impact of geography in determining the location of economic activity[14].

Given the importance now being ascribed to the Internet and ICT, it is interesting to ask exactly how the effects of ICT and the Internet are manifested in the economy. A good explanation of this can be found in Litan and Rivlan (2001). Specifically, they highlight that one of the impacts of the Internet on economic transactions is that it moves the economy closer to perfect competition. This causes profit margins to be lower than otherwise and provides firms with incentives to cut costs and be more efficient as they get exposed to competition from all over the world. In addition, Feldman et al (2001) notes that for businesses, the Internet facilitates lower purchasing costs, reductions in inventories,[15] lower cycle times, lower sales and marketing costs and more efficient and effective targeting of customer services and sales materials, while simultaneously allowing customers greater choice, convenience and the potential for increased customization. As well, business research is facilitated by the Internet in that it is easier to find large amounts of information, which can be moved around quickly and cheaply.

Furthermore, as Litan and Rivan (2001) point out, advances in ICT and the Internet, because they permit the inexpensive transmission of a lot of information quickly, allow routine transactions – making payments; processing and transmitting financial information; record keeping; search and analysis; ordering, invoicing and recruiting; getting information to suppliers, employees and customers – to be undertaken with less resources, utilizing Web-based technology[16]. They explain, as well, that manufacturing firms are able to use Intranets and other Web-based technologies to share information easily and cheaply across the organization, cutting the cost and improving the accuracy of accounting, ordering, tracking, invoicing, recruiting and other routine functions[17]. In addition, Web-based technology allows firms to manage supply chains more effectively and reduce inventories. These savings are manifested in the firm through better scheduling, improved information-sharing across the company, or in more efficient interaction with other firms in the supply chain.

As Wolfe and Salter (1997) note, the Internet and developments in ICTs allow for an expansion of the informational or codified component of knowledge. It is easier and cheaper to transmit and copy large amounts of information. Hence, being in a peripheral location is not necessarily an impediment to accessing and sharing information in the knowledge-based economy.[18]

Obviously, the evidence exists to support the idea that the Internet and ICT have had a positive impact on productivity and that there has been an increased ability to transmit and share information. However, this does not imply that geography is no longer a significant influence on economic activity. While this issue is dealt with in more detail below, it sufficient to note that Lacas et al (2001), in a review of the literature, finds that geography, rather than being irrelevant in determining the location of economic activity in a knowledge economy, is becoming more important. Specifically, they suggest that "IT will accelerate the forces of centralization and geographic concentration." In their assessment, this concentrating effect occurs because: *IT increases the possibility of centrally managing operations, especially for activities that involve economies of scale and IT is not a substitute for interpersonal communication, but is, rather, complementary and in fact increases the demand for face-to-face contact*.[19] In other words, the Internet facilitates things being done from a central point and the tacit nature of knowledge necessitates more face-to-face meetings.

What is clear in the literature is that the transformation from a goods-producing economy to a service-producing economy has increased the value of ICT investment, where the role of ICT is one of an "enabler". That is, investment in ICT reduces the costs of processing information, and networking and contributes to increased co-operation between firms. A snapshot of the ICT industry in Canada is given Table 1.

As this data demonstrates, the ICT industry in Canada is concentrated within four provinces - Ontario has the highest concentration of ICT firms with 46.3 per cent; Quebec with 22.4 per cent; British Columbia with 12.4 per cent; and Alberta with 11.9 per cent. Ninety-three per cent of all the ICT firms in Canada are located in those four provinces. The lowest per centage of Canadian ICT businesses in 1999 was in Prince Edward Island (0.18 per cent), which was just behind Newfoundland and Labrador (0.63 per cent). The total per centage of Canadian ICT businesses located in the Atlantic region was 3.56 per cent in 1999. Unambiguously, the ICT industry is under-represented in all of the Atlantic Provinces. For example, Newfoundland and Labrador's share of the Canadian population is approximately 1.8 per cent and it contributes 1.3 per cent of the Canadian economy, yet its share of ICT firms is 0.6 per cent or one-third the size that one might expect on the basis of population. As well, ICT firms compose about three per cent of all firms in Canada, but make up about 1.5 per cent of Newfoundland and Labrador's firms. Again, Newfoundland and Labrador's ICT industry appears to be under-represented in the overall distribution of provincial businesses vis-à-vis the Canadian average.

Table 1: ICT Businesses in the Canada and the Provinces - 1999.[20]

Province	% ICT of Total Firms	% ICT of Canada ICT
Canada	2.98%	100%
Newfoundland	1.45%	0.63%
PEI	1.01%	0.18%
Nova Scotia	1.89%	1.57%
New Brunswick	1.61%	1.18%
Quebec	2.76%	22.40%
Ontario	4.06%	46.29%
Manitoba	1.56%	1.90%
Saskatchewan	0.93%	1.45%
Alberta	2.81%	11.88%
BC	2.53%	12.36%

It is also interesting to examine the geographic distribution of ICT firms within Newfoundland and Labrador and consider how that distribution has changed over time. This is provided in Table 2.

Table 2: Areas With More than 1% of Newfoundland & Labrador's ICT Firms[21]

1998

Community	# firms	% of NF ICT
Grand Falls - Windsor	4	1.22%
Harbour Grace	4	1.22%
Labrador City	4	1.22%
Kippens	5	1.52%
Torbay	5	1.52%
Gander	6	1.82%
Stephenville	6	1.82%
Clarenville	7	2.13%
Paradise	7	2.13%
CBS	9	2.74%
Happy Valley - Goose Bay	9	2.74%
Corner Brook	12	3.65%
Mount Pearl	23	6.99%
St. John's	166	50.46%
Other communities	62	18.8%
Total	329	100.0%

2000

Place	# firms	% of NF ICT
Placentia	4	1.04%
Portugal Cove-St. Phillip's	4	1.04%
Torbay	4	1.04%
Grand Falls - Windsor	5	1.31%
Labrador City	5	1.31%
Gander	6	1.57%
Stephenville	6	1.57%
Paradise	7	1.83%
Corner Brook	9	2.35%
CBS	10	2.61%
Clarenville	10	2.61%
Happy Valley - Goose Bay	11	2.87%
Mount Pearl	38	9.92%
St. John's	192	50.13%
Other communities	72	18.8%
Total	383	100.0%

For example, in 2000, there were 383 ICT firms in Newfoundland and Labrador. The largest concentration was in the St. John's region, which accounted for 67 per cent of the ICT firms in Newfoundland and Labrador. However, the City of St. John's was the base of operations for slightly more that 50 per cent of Newfoundland and Labrador's ICT firms. While the proportion of ICT firms found in the City of St. John's is basically unaffected between 1998 and 2000, the regional share had dropped slightly to 65 per cent. As well, Mount Pearl recorded the largest increase (65 per cent) in the number of ICT firms between the years 1998 and 2000 and Corner Brook, with 25 per cent less ICT firms, saw the largest drop.

As evident from the discussion above, the Internet represents the platform where many knowledge-based activities take place. It is a mechanism through which Newfoundlanders and Labradorians can participate in knowledge-based activities and contribute to innovation.

Household Internet usage worldwide has experienced a phenomenal growth in recent years. By way of illustration, consider that access to the Internet by Canadian households has grown by nearly fourfold from 1996 to 2001.[22] The average Canadian family utilizing the Internet spends 32 hours per week on the Internet – 11.5 hours are devoted to entertainment, 8.8 hours are consumed with work related activities, 8.8 hours are spent communicating with others, 7.6 hours are invested in education activities and 3.8 hours are taken up with e-banking and investments.[23] Access to the Internet has opened up opportunities for Canadian households and for small business owners. Households and businesses can now purchase on-line. They can research issues relevant to their daily operations more quickly and conveniently than in the past. As well, for small businesses the Internet opens new markets, provides improved ways of advertising their services and allows them to sell into markets that otherwise were not accessible to them. Furthermore, the impact of the Internet is being felt in the workplace and throughout the school system.

Household Internet penetration in Newfoundland and Labrador jumped significantly to 46 per cent in 2000.[24] This rate is below the Canadian average, but Newfoundland and Labrador recorded the highest per centage increase of all provinces in that year. Technological change has brought the Internet from universities to households and businesses and Canadians are becoming "connected" at an ever increasing rate. With the explosion of the information highway, the Internet has pervaded all aspects of the lives of Canadian households. But, a digital divide appears to exist between various groups of Canadians and some families may be falling through the "net", being unable to reap the benefits that accrue to others on the digital express.

Much has been written about the digital divide. The concept refers to the increasing disparity between those who have "useful access" to information technology (IT) and those who do not. The literature suggests that access and use of IT is related to social and economic factors. For example, Lynch and Locke (2001) found that usage was sensitive to income, age, education and other family characteristics. They found that well-educated, high-income households, living in urban areas were more likely to take advantage of the opportunites that exist on the information highway. Sciadas (2002), estimated the digital divide by focusing on the relationship between income and Internet use. He found that the gap was closing for certain income groups but the gap between the highest and lowest income groups still exists.

An expanded understanding of the digital divide was presented by Lynch and Locke (2002), where they provided provincial and urban/rural estimates of the digital divide for Atlantic Canada. They found that urban usage for high income/well educated households is higher than the urban estimates for Prince Edward Island, Nova Scotia and NewBrunswick. Estimates for Newfoundland and Labrador were consistently below the estimates of the other three Atlantic Provinces. For example, Newfoundland and Labrador is the only Atlantic province below the Canadian average for estimated urban usage. These results illustrate the existence of a regional urban digital divide, with Newfoundland and Labrador's urban household Internet usage significantly below the other Atlantic provinces. Lynch and Locke (2002) also found that there was a significant decrease in the estimated probability of Internet usage between urban and rural areas. For example, for high income households with university education, estimated Internet usage fell by 33 per cent moving from urban to rural Newfoundland and Labrador. They calculated the urban/rural digital divide as the gap or difference between the probabilities of Internet usage in urban and rural areas.[25] In Newfoundland and Labrador, the urban/rural gaps were much higher when compared to both Canada and the other Atlantic provinces. In fact, some of the gaps increased over time. For example, the gap increased from 24.7 per cent in 1997 to 30 per cent in 1999 for the low income/less than high school category. Their results indicate that the urban/rural digital divide is wider in Newfoundland than elsewhere. Newfoundland and Labrador remains an outlier, with both urban and rural, household Internet usage significantly below the other Atlantic Provinces.

Very little research has been done from an inter-provincial perspective on business Internet usage. There have, however, been a few surveys which have examined Internet usage by firms. For example, estimates from the Canadian Federation of Independent Business indicate that Internet use by Newfoundland and Labrador's small and medium enterprises in 2000 was 15 per cent below the national average.[26]

The estimates of the urban/rural digital divide (see Lynch and Locke (2002)) indicate the existence of a large urban/rural difference in Internet usage and one that has remained relatively constant over time. The concept of Internet usage has no meaning if one does not have access to the Internet.

Lynch and Locke (2002) compiled selected statistics describing broadband connectivity of 1,104 communities representing a population of 2,232,925 in Atlantic Canada.[27] They found that there were significant variations in the provision of services across provinces. Nova Scotia has the highest access rate with 76 per cent followed by both Prince Edward Island and Newfoundland and Labrador with 58 per cent and New Brunswick with 52 per cent.[28] The average size of communities without broadband access ranges from 766 in Newfoundland and Labrador to 1,199 in Nova Scotia. The average community size where broadband is offered is the highest in Prince Edward Island with 15,750 followed by 10,736 in New Brunswick, 8,008 in Nova Scotia and 3,931 in Newfoundland and Labrador. In Newfoundland and Labrador there is a large discrepancy between average community size for those communities that have access through cable (3,905) and those communities that have access by Digital Subscriber Lines (DSL) (19,220). The opposite is true for New Brunswick (29,880 cable versus 10,736 DSL) and the difference is much smaller in both Nova Scotia and Prince Edward Island. As well, how people get on the information highway is different across provinces. In Newfoundland and Labrador, access is primarily through cable, where 71 communities have access through cable and 10 communities have DSL and of those 10 communities, nine also have cable access.[29] More communities in New Brunswick have access via DSL (35) than cable (nine), whereas in Prince Edward Island and Nova Scotia access is more evenly divided between the two technologies.

Given that broadband is expensive and economies of scale apply, large centres with sufficient subscribers will get access first. As such, rural usage is restricted to narrowband access, the type of access that existed in urban communities 10 years ago. The data on access illustrates that broadband technology (more so DSL than cable) is located in larger communities that are not “rural” communities. Some small communities do have access, but they are typically located close to larger communities.

Finally, what is surprising is that average community size, where broadband is offered, is lowest in Newfoundland and Labrador. Newfoundland and Labrador has 28 communities with populations under 1,000 with broadband access. This is seven times greater than New Brunswick (with four communities) and twice as much as Nova Scotia (14 communities). There are no communities with populations less than 1,000 with broadband access in Prince Edward Island. This would suggest that rural access to broadband services is more widespread in Newfoundland and Labrador than other rural areas of Atlantic Canada. One would expect that greater access would translate into greater usage. However, the econometric analysis of usage indicates that the largest urban/rural digital divide was in Newfoundland and Labrador when compared to Canada and the other Atlantic Provinces.[30] The paradigm “build it and they will come” does not appear to apply in rural Newfoundland and Labrador.[31]

Private and Social Rates of Return on R&D

R&D is considered one of the most important determinants of innovation since it is used to generate knowledge. The benefits of R&D spill over to other firms and industries contributing to total factor productivity

IT and Knowledge-Based Economy Summit
Government of Canada, 1997

As noted above,[32] there is a substantial body of literature which demonstrates that while research and development activities of firms generates high rates of returns for the firms themselves, the benefits of this activity affect the productivity of other firms. That is, the empirical evidence confirms that research and development activity creates positive externalities, which is another way of saying that the social return to research and development exceeds the private return.[33] Since firms undertaking this activity cannot benefit from these external effects, they do not take them into account in deciding the amount of research and development to perform and, as such, there is an under-investment in research and development. In fact, Griffith (2000) states that one of the main justifications for government subsidies to research and development is that the social return on research and development exceeds the private return.[34] In addition, there is empirical support for the fact that the spillover of research and development activities occurs across geographical boundaries.[35]

The empirical evidence demonstrates that in addition to generating spillovers, research and development activities are associated with very high private rates of return. In fact, these returns seem to be high in relation to other investment opportunities available to the firms. Given these high rates of return, one might expect to observe even higher levels of research and development being undertaken by private sector firms. Consequently, it is legitimate to ask: why profit-maximizing firms do not pursue more of these activities that generate very high rates of return? Possible explanations have been offered by Mohnen (1999), Griffith (2000), Eaton et al (1998) and Feldman (2001). These additional explanations for suboptimal levels of investment in research and development activity by private sector firms are:

- Financial market imperfections, combined with informational asymmetries, result in insufficient access to private sector capital to fund all of the research and development opportunities that have a rate of return in excess of the opportunity cost of capital;
- There may be supply constraints in existence. For example, there is not an infinite supply of research scientists and engineers around to undertake these activities. Consequently, since these specialized skills are required to undertake research and development and may be in short supply, firms have to be selective in which projects are undertaken. This, of course, implies that not all research and development activities will proceed, even if they pass the hurdle rate of return employed by private sector firms;
- Even if the gross-of-tax rate of return to the private sector is high, the presence of high tax rates in a jurisdiction can lower the after-tax rate of return sufficiently to deter investments in some research and development activities; and

- The size of the market in which the firm is operating may be too small for the investor to recoup his/her investment. The extent of this problem is lessened with an elevated export propensity on the part of the firm.

Another possible reason for the lower level of private sector research and development activity is provided by Bessen (2001), who draws attention to the fact that it is not costless for a firm to utilize its own research and development for productive purposes. These costs, which are referred to as "adoption costs" by Bessen (2001), are strong complements to research and development expenditures. It is argued in that study that if adoption costs were included with normal research and development expenditures, then the rates of return estimated for private sector research and development would be more in line with the returns earned on other private sector investments. While this may help explain why private sector research and development activity appears to be out of line with other private returns, it does not diminish the significance of the fact that private returns fall short of social returns for research and development activities. As such, there still may be a role for government in trying to ensure an efficient level of investment by bringing the private and social rates of return back in line.

At this point, it is informative to consider another issue raised in the literature and that relates to the capacity of firms to absorb research and development innovations from outside sources.[36] As described in Martin et al (1996):

> *Individuals need to develop substantial skills and to expend considerable resources to understand codified knowledge…The ability to understand codified knowledge requires organizations to maintain a substantial and often expensive research capability. Without this capability, organizations would be unable to interpret and derive value out of the growing body of codified knowledge…codified knowledge is only capable of transmitting partial information, and the application of that information also requires personal interactions for the transmission of associated tacit knowledge and skills.*

In other words, as Rosenberg (1990) points out, in order for firms to effectively benefit from the diffusion of research and development activities of other firms, they need to possess a certain knowledge base that is fostered by their own research and development activities.[37] That is, the magnitude of the spillover effects of research and development are contingent upon the research and development activities of the recipient firms. The implication of this is that the lack of research and development activities in the private sector limits their productivity growth through direct and indirect mechanisms.[38] The direct effect results because their innovation activity is low and their development of new goods or processes for their own benefits is suboptimal. The indirect effect occurs because they have a diminished capacity to take advantage of research and development spillovers that occur through the activities of other firms. Accordingly, areas characterized by lower research and development are hit by the double whammy – less new goods and processes developed locally and a lower ability to utilize research and development from elsewhere.

The evidence considered above unambiguously highlights the need for some kind of intervention to enhance the research and development activities of local firms. However, there is a literature that casts doubt on the need or effectiveness of government intervention in enhancing research and development activity in the private sector. For example, Mamuneas and Nadiri (1996) and David et al (2000) report that research and development funded through government grants simply crowds-out company private sector activity in many industries.[39] This finding is corroborated by Goolsbee (1998), which finds that government subsidies mainly increase the salaries of scientists and engineers and may not generate any new innovations.

Although these empirical findings tend to call into question the efficiency of government support for research and development, other research suggests that these findings are peculiar to particular programs and do not carry over to all types of support.[40] For example, Feldman (2001) finds that government support, rather than discouraging private sector research and development activity, was integral to the research and development undertaken by private sector firms. This was demonstrated by the fact that these firms would not have proceeded with the research and development activity in the absence of the government support or they would have substantially scaled back their plans. As well, Feldman (2001) finds that government subsidies attract additional funds from other sources for research and development activities within private sector firms. These finding are clearly at odds with the crowding out hypothesis.

The discussion up to this point has focused on theoretical and empirical issues pertaining to research and development and the knowledge economy. It is useful now to consider how Newfoundland and Labrador is performing in terms of indicators of research and development and patent activity. A consideration of these indicators will help determine those areas on which the Royal Commission needs to focus in terms of policy development to strengthen Newfoundland and Labrador's position within the Canadian economy.

Drawing on Locke and Lynch (2001), the following provides an overview of Newfoundland and Labrador's research and development activity. In interpreting these statistics, it is important to understanding that Newfoundland and Labrador's shares of the Canadian population and economic activity in 1999 were 1.8 per cent and 1.3 per cent, respectively.

In 1999, $17.2 billion of research and development was performed in Canada. Newfoundland and Labrador accounted for $125 million, representing a 0.7 per cent share of the Canadian total. When the $125 million was normalized for the size of Newfoundland and Labrador's economy or population, this represented one per cent of its GDP and corresponded to $231 per capita. To provide some context for these estimates, consider that the corresponding data for Ontario were: $8.7 billion in total research and development performed, 50.5 per cent of the Canadian total, representing 2.2 per cent of Ontario's GDP and corresponding to $756 per capita. The Canada-wide averages were: 1.8 per cent of GDP and $565.4 per capita. Clearly, Newfoundland and Labrador's research and development intensity (R&D/GDP) is only 39 per cent of the Canada-wide average and about 32 per cent of that exhibited in Ontario. In per capita terms, Newfoundland's research and development effort is coming in at 41 per cent of the Canadian average or 31 per cent of the Ontario average.

Turning to research and development performed by the business sector in 1999, one observes that $9.8 billion was undertaken across Canada and Newfoundland and Labrador was responsible for only $16 million. This represents 0.2 per cent of the Canadian total, 0.1 per cent of Newfoundland and Labrador's GDP, or $29.6 per capita. By way of comparison, Ontario had: $5.4 billion in research and development performed by the business sector, 55.4 per cent of the Canadian total, 1.3 per cent of their GDP and $472.4 per capita. The Canada-wide averages were: one per cent of GDP and $322 per capita. Controlling for the respective sizes of their economies, Newfoundland and Labrador had only eight per cent of business sector research and development intensity that existed in Ontario and only 10 per cent of the Canada-wide estimate.

In terms of research and development performed by the higher education sector, Newfoundland and Labrador is doing relatively well. For instance, in 1999 there was $5.2 billion of research and development performed by that sector and Newfoundland and Labrador accounted for $79 million or 1.5 per cent of the Canadian total. This corresponded to 0.6 per cent of Newfoundland and Labrador's GDP and or $146 per capita. The corresponding data for Ontario were: $2 billion in research and development performed by the higher education sector, 39 per cent of the Canadian total, 0.5 per cent of their GDP and $174.5 per capita. The Canada-wide averages were: 0.5 per cent of GDP and $169 per capita. Controlling for the size of the economies, one observes that Newfoundland and Labrador's research and development intensity associated with the higher education sector exceeds the Canada-wide estimate and that found in Ontario. However, when this comparison is made in per capita terms, it is clear that Newfoundland and Labrador's research and development effort in the higher education sector falls short of the Canadian average (86 per cent) and of that observed in Ontario (83 per cent).

It is also interesting to examine research and development performed by the federal government. In 1999 there was $1.9 billion of research and development performed by the federal government of which $25 million occurred in Newfoundland and Labrador. This represents 1.3 per cent of the Canadian total, 0.2 per cent of Newfoundland and Labrador's GDP, or $46.2 per capita. The corresponding estimates for Ontario were: $1.1 billion in research and development performed by the federal government, 58.5 per cent of the Canadian total, 0.3 per cent of its GDP and $94.4 per capita. The Canada-wide averages were: 0.2 per cent of GDP and $61 per capita. Relative to the size of its economy, the amount of research and development performed by the federal government is equivalent to that which occurs Canada-wide. However, it does fall short of that which is observed in Ontario, but that reflects the National Capital Region being located primarily in Ontario.[41]

The final sector performing research and development is the provincial sector. In 1999, $0.4 billion of research and development was performed by that sector and $5 million occurred in Newfoundland and Labrador. This represents 1.2 per cent of the Canadian total, 0.04 per cent of Newfoundland and Labrador's GDP, or $9.2 per capita. The corresponding information for Ontario is: $0.16 billion in research and development performed by the provincial sector, 40 per cent of the total, 0.04 per cent of GDP and $14.2 per capita. The Canada-wide averages were: 0.04 per cent of GDP and $13.4 per capita. Newfoundland and Labrador is equivalent to Ontario and Canada-wide when controlling for the size of their respective economies. However, in per capita terms, the research and development performed by the provincial sector in Newfoundland and Labrador was 69 per cent of the Canadian average and 65 per cent of the Ontario average.

Another way of looking at this data is to compare the relative shares of research and development performed in Newfoundland and Labrador by each sector. The relative shares observed in 1999 were:

- Higher education – 63.2 per cent of total research and development;
- Business – 12.8 per cent of total research and development;

- Federal government – 20 per cent of total research and development; and
- Provincial sector – four per cent of total research and development.

The corresponding shares for Canada as a whole were:

- Higher education – 29.9 per cent of total research and development;
- Business – 57 per cent of total research and development;
- Federal Government – 10.8 per cent of total research and development; and
- Provincial sector – 2.4 per cent of total research and development.

What message should be taken from these statistics? Obviously, Newfoundland and Labrador is not performing well in terms of research and development activity and this is particularly true for research and development undertaken by the business sector. As well, it is interesting to note that nearly two-thirds of research and development comes from the higher education sector in Newfoundland and Labrador, while the corresponding figure Canada-wide is 30 per cent and the business sector performs nearly 60 per cent of research and development in Canada, but it only accounts for slightly more than 10 per cent in Newfoundland and Labrador. Given the different incentives for commercializing research and development in the higher education and business sectors, this difference is significant and may have implications for how well Newfoundland and Labrador can do in the knowledge economy.

Another indicator of innovation is patents, which assign legal rights to their owners over particular ideas or knowledge. They represent one way to protect the intellectual property embodied in a new product or process. That is, patents constitute an effective means of protecting and capitalizing on the research and development activities contained within innovative products or processes. Hence, the number of patents issued in a given jurisdiction is an indirect measure of innovation outcomes.[42]

Newfoundland and Labrador is characterized by very low levels of patent activity. For example, over the last 100 years, Newfoundlanders and Labradorians registered between zero and eight patents annually in Canada. Furthermore, the annual pattern of patent registration resembles a random walk. As well, in 1999 Newfoundland and Labrador's share of patents issued in Canada was 0.3 per cent. This was one-sixth of its share of population and one-quarter of its share of Canadian economic activity. When one examines the patents issued in the United States to residents of Canada, Newfoundland and Labrador's relative position does not improve. For example, in 1999 residents of Newfoundland and Labrador registered seven patents in the United States, which represented 0.2 per cent of the patents issued in the United States to residents of Canada during 1999. In other words, patent activity in Newfoundland and Labrador has been historically low and has not improved in recent years. Certainly, Newfoundland and Labrador is falling behind the other provinces in terms of innovation activity and innovation potential. Given the importance of innovation activity to productivity and for an area's standard of living, this should give policy makers cause for concern.

The Distinction Between Tacit and Codified Knowledge – Is it Important?

> *Codified knowledge and tacit knowledge differ importantly in that the former can be written down (in patent, drawing, design, formula…and transmitted) whilst the latter is skill based, talent based, experimental and therefore is difficult to transfer except through demonstration (learning by doing) or appropriation (hiring the person who has a talent or the experience that you want).*
>
> *Some Economic Consequences of Knowledge, Information and ICTs*
> *John de la Mothe, 2000*

Knowledge is more than information. Feldman et al (2001) points out that while data is synonymous with information, it is not equivalent to knowledge. From their perspective, "knowledge exists when an individual understands what to do with the information, what it implies, what its limitation are and how to create value from it." While the Internet and ICT facilitates the transmission of large amounts of information[43], the same conclusion does not necessarily hold for the transmission of knowledge. The translation of information into usable knowledge is not as straightforward as one would think, as it consists of a more complex, cognitive process.

Another way of coming at this issue is to distinguish between codified and tacit knowledge. Martin et al (1996) reports that advances in ICT have facilitated our ability to codify knowledge and, in fact, they have argued that it "has intensified the movement towards the codification of knowledge". However, the tacit dimension of knowledge, as pointed out by Griffith (2000), implies that it takes time and effort to explain this information, and the ideas contained therein, to others so that it can become useful knowledge.[44] Moreover, as Feldman et al (2001) highlights:

> *when knowledge is highly tacit in nature, face-to-face interaction and communication are important to transmit knowledge and geographic proximity may promote the transmission of knowledge. The less codified and the more difficult it is to articulate the knowledge, the greater the need for frequent face-to-face meetings and the greater the resulting degree of centralization in geographic organization.*

That is, the tacit nature of knowledge will help determine whether geography is more important to the location of economic activity in a knowledge-based economy.

In the context of considering the knowledge-based economy, it important to recognize that while, as noted in Feldman et al (2001), knowledge is the most decisive input for innovation, innovation consists of "the ability to blend and weave different types of knowledge into something new, different and unprecedented that has economic value." As Feldman et al (2001) argues:

> *Innovation, at a fundamental level, is a social process that bridges individuals from different disciplines with different competencies, distinct vocabularies,*

and unique motives. Innovation involves creativity and is a cognitive process for individuals…the tacit nature of knowledge and the social nature of the innovation process limit the impact of the Internet.

In other words, the tacit nature of knowledge implies that close proximity might be required to exploit the full potential of knowledge in the new economy. Moreover, this may help explain why the bulk of research and development expenditures in Canada are concentrated in a few provinces and a similar pattern is observed in the United States.[45]

Proximity: Does Geography Matter?

Now, the world is moving rapidly into a new era when growth and well-being depend on human capital and innovation…In this era, we – both the Atlantic region, and Canada as a whole – have the opportunity to leave some of yesterday's obstacles behind, and to build on our strengths to hurdle the barriers of today and tomorrow.

Leading to Competitiveness: Atlantic Canada's Knowledge-Based Future
Association of Atlantic Universities, 2002

If advances in ICT and the Internet lessened the impact of geography on the decision of where to locate economic activity, then it would have huge implications for peripheral areas such as Newfoundland and Labrador. Unfortunately, as Houghton and Sheehan (2000) point out, there seems to be an increasing tendency for firms to co-locate. This is explained by the need to share tacit knowledge. Polese et al (2002) and Beaudin and Breau (2001) find evidence that high-technology firms in Atlantic Canada tend to concentrate in urban areas. The finding that geography matters in a knowledge-based economy is not only a Canadian reality. For example, knowledge clusters such as the Silicon Valley in California, Route 128 in Boston, the Wireless Valley in Finland and Oxbridge in England are all example of this phenomenon.[46] As well, Funke and Niebuhr (2000) provide empirical support for the proposition that in Germany, proximity is an important determinant of how knowledge spillovers affect productivity and growth. That is, they find that research and development spillovers are "geographically bounded and constitute a significant source of regional productivity growth". Anselin (1997) finds that knowledge spillovers from universities in the United States extended over a 50 mile range. Feldman and Audretsch (1999) highlight that the geographic area associated with a knowledge spillover is limited. As well, Lacas et al (2001), in their review of the literature, note that "growth activities associated with the knowledge economy are sensitive to agglomeration economies." Looking at knowledge spillover from universities, Jaffe (1989), and Acs et al (1992) find that knowledge spills over from the universities to industries that are located close to these institutions. Katz (1994) demonstrates that university-to-university collaboration is also strongly influenced by geographic proximity.

As Martin et al (1996) suggest, "locational advantages reflect cumulative investments in human and technological capabilities." In other words, geography is no less important in the knowledge economy and may even be more important. This is explained by Martin et al (1996) in the following way:

Why does localization occur? The R&D process is characterized by a great deal of interaction between individuals in firms and research institutions such as universities. In order to develop new forms of knowledge or to transfer existing forms of knowledge, research performers and users often need close, personal interaction, given the importance of know-how (i.e., tacit knowledge that cannot be codified). This need to be there forces firms and individuals to congregate in particular localities in order to share and transfer information quickly and effectively. These lines of personal *interaction, often informal in character, are important elements of the geographical constraints on innovation.*

That is, while the Internet and ICT make it easier to transfer information, the tacit nature of knowledge still requires face-to-face meetings, which are facilitated by the actors being close to each other. Audretch (1998), Krugman (1998), and Feldman et al (2001) also point to the role of tacit knowledge in limiting the geographic boundary associated with knowledge spillovers.

Does this necessarily imply bad news for peripheral regions such as Newfoundland and Labrador? No, not necessarily, the province can draw upon the knowledge capacity associated with Memorial University. There is no obvious reason why the university could not or should not fulfill the role of enhancing the knowledge base of the province, the benefits of which could spillover into the innovation activities of the private sector. The role of the university in a knowledge economy is dealt with more extensively in the next section.

The Role of Universities and Human Capital in a Knowledge Economy

Canadian colleges and universities make significant contributions to Canada's social well-being and economic growth in their deliberate ways. First and foremost, they contribute directly to the nation's economic performance by educating and graduating highly qualified personnel to meet the increasing needs of the workplace; they expand the boundaries of knowledge in all disciplines through basic and applied research, as they develop concrete solutions to selective challenges of industry and government and they contribute to the economic and social well-being of their surrounding communities.

A Canadian Innovation Agenda for the Twenty-First Century
Standing Committee on Industry, Science and Technology
Government of Canada (2001)

As the above quote indicates, the role of universities in today's economy is multifaceted. It is becoming more recognized that post-secondary educational institutions have an increasingly important role to play in promoting and facilitating local economic development in a knowledge-based economy. Furthermore, this role will likely become more important over time. A classic example of the role research institutions can play in today's economy is provided by Saxenian (1994), which demonstrated that the local research infrastructure helped shape the innovation capacity of Silicon Valley and Route 128 in Boston. Miner et al (2001), Feller (1990), Association of Atlantic Universities (1999), Doutriaux and Barker (1995), and Martin and Trudeau (1998)[47] have also highlighted the link between universities and economic development. Other analysts have emphasized the pivotal role that universities play in facilitating and enhancing innovation, productivity and competitiveness of local areas and local firms.[48]

Despite the potential for the higher education sector to contribute to growth and development within the local economy, this may not always be realized.[49] There are many reasons why the post-secondary education system may not generate the kind of impacts on the local economy that are possible. Some of these are:[50]

- It may not be in the university's mission statement to utilize its human capital for the benefit of the local area. That is, it is not one of its stated objectives;
- There may be little experience of university researchers interacting with industry;
- Within an institution, applied research may not be seen as a legitimate function of the university;[51]
- The industrial composition of the area may not be conducive to fully exploiting the potential spillover of knowledge that is possible from a university;
- Labour force characteristics and social capital variables may also inhibit the knowledge transfers from a university to the local area;

- There may be a general apathy on the part of university researchers to form close links with industry;
- The university may not be competitive in terms of what it can offer local industry to deal effectively with their problems;
- Local industry may not have the absorptive capacity to utilize the knowledge spillovers from the university. As noted above, the absorptive capacity of firms is tied to their own research and development activities and if this is low, then they may not be able to benefit from knowledge spillovers from the university;
- Promotion and tenure criteria utilized in universities, by not attaching significant weight to university-industry collaboration, may act as a barrier to economic development benefits that could emanate from the university; and,
- Graduates may be leaving the area to take advantage of employment opportunity elsewhere in the country – the so-called brain drain. Consequently, the knowledge embodied in these students is exploited by other areas.

It is worthwhile considering how Memorial University fares in regard to potential constraints. As its Mission Statement indicates, Memorial University defines as part of its mandate "to undertake research on the challenges this province faces and to share its expertise with the community." However, Locke et al (2002) demonstrate the majority of Memorial University researchers do not have a lot of experience collaborating with industry and a significant per centage of Memorial University's faculty question whether industry collaboration is a legitimate function of a university. There does not appear to be a general apathy on the part of university researchers, rather there appears to be a concern that their areas of expertise may not have any commercial appeal that could be utilized by industry. As well, Locke et al (2002) raise the possibility that university-industry collaboration in Newfoundland and Labrador may be impeded by the promotion and tenure criteria utilized at the university. Sheppard et al (2002) indicate that the local SMEs might not be as receptive to collaborating with the university as might be found in other jurisdictions. This may be explained, in part, by the relatively low level of research and development activities performed by the business sector in Newfoundland and Labrador. Furthermore, as explained in more detail below, the brain drain does appear to be a problem for the Newfoundland and Labrador economy. Finally, there is a concern that Atlantic Canadian universities, while currently competitive, may not be able to contribute fully to the economic development potential of the region in the future.

> *In the knowledge economy, economic competitiveness requires competitive universities. Unless action is taken, Atlantic Canada's universities are unlikely to remain competitive. If the universities lose their best professors, they will lose their best students. The quality of education in Atlantic Canada will drop. Research and technology transfer will dry up. The quality of the workforce, the level of business development, the growth of employment – all will be negatively affected.*
>
> *Association of Atlantic Universities (1999)*

While training students is probably the most significant way in which knowledge gets transferred from the university sector to the rest of the economy, the collaboration between university researchers and industry is another way that the university contributes to economic growth and prosperity in a knowledge economy. It is important to recognize that there are various types of collaborations that exist between universities and industry. The types of collaboration that have been considered in the literature are:[52]

- sponsored research contracts;[53]
- faculty consulting activities;
- informal contacts – either personal friendships[54] or through academic conferences and industry-university networking sessions;
- through students that have been trained by university researchers and absorbed into industry; and
- formal technology transfer agreements such as licenses.

The benefits of university-industry collaboration have been well established in the literature. For example, OECD (2000) has suggested that the interaction between universities and industry is becoming increasingly important for the innovation system itself; Cockburn and Henderson (1998) demonstrate that knowledge spillovers between universities and industry are tied to the degree to which the two collaborate; Adams (1990), Jaffe (1989) and Acs et al (1992) establish the presence of knowledge spillovers between the university and industry and that being close to a university is an important determinant of the extent of these spillovers; Link and Rees (1990), and Acs et al (1994) find that SMEs benefit more from university-based knowledge spillovers than larger firms, which have the capacity to undertake their own research; Mansfield (1991) finds that public sector research has a high return and that a significant amount of private sector products and processes could not have been developed without academic research; Feldman (2001) reports that collaboration between industry and university researchers has had a positive impact on innovation; Globerman (2000) indicates that closer ties between academic and industry research promotes the accumulation and diffusion of technical knowledge; Martin et al (1996) argues that good personal links between industry and public sector are crucial for collaboration between the two and are vital to maintain the connection between basic research and technological development; and Doutriaux (2000) suggests that there is an increased probability of innovation, profitability and growth for firms that collaborate with universities.

The connection between industry and the university sector has been increasing over time in Canada.[55] However, as Doutriaux and Barker (1995) point out, this has come mainly from larger firms. They suggest that "Canadian small- and medium-sized enterprises do not avail themselves of the technology and ideas coming out of universities". As well, Baldwin and Da Pont (1996) find that Canadian manufacturing firms were frequent users of university research.

In addition to collaborating with industry, universities transfer knowledge to the rest of the economy through the knowledge embodied in the students that they educate. As Martin and Trudeau (1998) suggest, firms utilize the knowledge embodied in the students to increase their productivity. In fact, Wolfe and Salter (1997) indicate that "the movement of doctoral and post-doctoral students into industry often provides the most effective method for transferring research results from the laboratory directly to industry." This point is also echoed by Gu and Whewell (1999).

While educating young people is an effective means of transferring knowledge from universities to the rest of the economy, this may not be helpful if these students leave upon graduation.[56] This may be a more important problem in peripheral regions that have been suffering from the so-called "brain drain". Lacas et al (2001) point out that the movement of skilled and educated workers from peripheral regions to central locations tends to accentuate regional disparity. In fact, Polese et al (2002) note that in a knowledge-based economy, the effect of the problem of out-migration of young, educated people is even more important. They suggest that education and the recruitment of skilled labour are integral to participation in the knowledge economy and they offer the following incentives to increase the attractiveness of peripheral communities to the young, educated workers who are also highly mobile:

1. Tuition or debt relief for university graduates who settle in targeted regions;
2. Scholarships for graduate or post-graduate internships in targeted regions;
3. Tax relief for students in post-secondary institutions in targeted areas;
4. Research chairs for institutions in targeted areas; and,
5. Increased focus on knowledge-transfer centers and allied learning, specifically via community colleges…including access to the incentives above.

Another independent effect that the university sector has upon the knowledge economy is through the research activity it undertakes. Wolfe and Salter (1997), in a review of the empirical literature, conclude that "publicly-funded basic research has a positive payoff…ranging from 20 to just under 50 per cent". In addition, Martin et al (1996) highlights the benefits from government-funded basic research. These are:

1. Increasing the stock of useful information;
2. New instrumentation and methodologies;
3. Skilled graduates;
4. Professional networks;
5. Technological problem solving; and,
6. Creation of new firms.

It is also important to recognize that, as noted in Government (1999), the Canadian federal government invests relatively less in university research that is the case in the United States. And, as mentioned in Robitaille and Gingras (1999), the gap between Canada and the United States in resources invested in university research is growing. Doutriaux and Barker (1995) find that public sector research funded by the private sector in Canada is increasing and Doutriaux (2000) notes that there is an increasing concentration of research in the largest, more research intensive universities in Canada. Unfortunately, this list would not include Memorial University.

However, as noted by Nordicity Group Ltd. (1997), Atlantic Canada has a relatively strong publicly-funded research and development infrastructure, but it may be "largely disconnected from the needs of the community." Consequently, one may have to look carefully at what types of research and development are being undertaken if one wishes to devise a strategy for enhancing economic development in a knowledge-based economy through university research.

At this point, it is worthwhile to consider what types of innovation activities are occurring at Memorial University. The most current and comprehensive source of this information is a 2002 report by the Atlantic Association of Universities.[57] The innovation activities listed in that report are provided in Appendix A. As impressive and as comprehensive as this list is, it needs to be considered with caution. First, there is no indication as to how significant these activities are to Newfoundland and Labrador's knowledge economy. Second, given the relatively low level of university-industry collaboration demonstrated in Locke et al (2002) and Sheppard, Locke and Lynch (2002), one ought to ask: how much more extensive could it become with elevated levels of collaboration between the university and industry? Given the dearth of research in this area, it is not possible to answer these questions at this time.

Although it may be overstating the obvious, in our opinion, high levels of education are imperative for the production and use of knowledge, which are prerequisites for success in the innovation process. The education system provides skills to the students and facilitates the generation of ideas that feed into innovation activities. Moreover, the education system defines the capacity of a province to undertake research and provides the skills required to participate in the knowledge-based economy. As well, the education system exposes people to the knowledge-based economy at a very early age.

As pointed out by Lattimore (2002), primary school education has "a positive effect on economic growth rates…and may be an important seed of economic development". While the empirical findings are mixed, there is evidence that education levels and economic growth are positively related.[58]

Along these lines, it is important to consider that Newfoundland and Labrador "leads" the country in terms of the proportion of its population with less than a high school education.[59] In 1990, for example, 38 per cent of the Newfoundland and Labrador population did not graduate from high school, while the corresponding number for Canada was 27 per cent. By 1998 this statistic had improved for all provinces. The Canadian average had fallen by nine per centage points to 18 per cent and the Newfoundland and Labrador rate declined by a similar amount (38 to 29 per cent).

However, the results are opposite for college and trade school graduates. By 1998 Newfoundland and Labrador had shot past all other provinces in terms of the proportion of its population with their highest level of education being college or trade schools. In 1998, for instance, 37 per cent of its population had achieved a trade school or college education. On the other hand, the Canadian average increased from 25 per cent (1990) to 31 per cent (1998).

At the high end of the educational spectrum Newfoundland and Labrador is below the Canadian average. For example, 18 per cent of Canadians had a university education in 1990. However, only 11 per cent of Newfoundlanders and Labradorians had a university education – the lowest in the country. By 1998, all provinces had improved in terms the proportion of its population that had acquired a university education. The Canadian average had increased by five percentage points, but Newfoundland and Labrador increased by only three percentage points (from 11 to 14 per cent). Again, Newfoundland and Labrador had the lowest increase in the country.

Still, in 1997, the proportion of Newfoundlanders and Labradorians possessing a bachelor's or first professional degree was 31.3 per cent, which was above the Canadian average and in the top half of the provinces. Therefore, in terms of the proportion of the population achieving an entry level university degree, Newfoundland and Labrador appears to be doing as well as other provinces.

One of the more important indicators of the capacity of a province to participate in the knowledge-based activities and to facilitate the innovation process is the proportion of its population that holds the more advanced degrees – Master degrees and earned doctorates. Newfoundland and Labrador falls below the Canadian average in terms of the proportion of its population that possessed a Master degree. Still, there is evidence that Newfoundland and Labrador's absolute and relative positions with respect to the other provinces is improving. By 1997 the proportion of its population that possessed a Master degree increased to 4.4 per cent from 3.2 in 1990.

Newfoundland and Labrador was one of the lowest provinces in the country for those who earned doctorate degrees. While the proportion of its population with earned doctorates had increased from 1991 to 1997, Newfoundland and Labrador had not kept pace with what was happening in the rest of the country. For example, in 1991 the Canadian average was 0.4 per cent, but only 0.3 per cent of Newfoundland and Labrador's population had an earned doctorate. By 1997 the Canadian average increased to 0.6 per cent and Newfoundland and Labrador had increased to only 0.4 per cent.

Overall, Newfoundland and Labrador's population exhibits relatively low education levels. For example, Newfoundland and Labrador students underperformed relative to their counterparts in other provinces in terms of School Achievement Indicators Program (SAIP) assessments for mathematics content and Newfoundland and Labrador's relative position had not improved from 1993 to 1997. The education levels of Newfoundlanders and Labradorians, like the rest of Canada, have been improving, but the improvement has been in the more technical trades, rather than at the university level. Again, while the proportion of Newfoundlanders and Labradorians with a university education has been improving, it continues to fall behind the rest of Canada. This is particularly disturbing because the advanced degrees are crucial to success in the innovation process.

There is no doubt that the relatively lower levels of education attained by Newfoundland and Labrador's population is a serious concern, however, the greatest threat to the knowledge base in Newfoundland and Labrador is the out-migration of knowledge-based workers. The younger generation, those between the ages of 15 and 29, possess the greatest amount of knowledge capital compared to all other age cohorts. A Royal Bank analysis of interprovincial mobility of highly skilled workers reported that between 1991 and 1996 seven provinces experienced net out-migration.[60] The province that recorded the largest negative net interprovincial migration was Newfoundland and Labrador. In that period, Newfoundland and Labrador had the highest outflow of university graduates and the highest outflow of knowledge workers.[61] For the years 1996 to 2001, Newfoundland and Labrador lost an average of 6,415 per year due to out-migration and 68 per cent of those individuals have come from the age cohort 15 to 29. In that period, there is an upward trend in those leaving in that age category. For example, in 1996, 58 per cent of those who out-migrated came from the 15 to 29 age cohort. In 2001, 72 per cent of those who left the province were between the ages 15 to 29.[62] An analysis of the migration rates of trade school, college and university students within two years of graduation reveals that Newfoundland and Labrador lost a significant number of graduates within two years of graduation.[63] An analysis of out-migration prepared by the Newfoundland Statistical Agency reported that the proportion of those leaving Newfoundland and Labrador with a university degree has been rising over time. For example, 11 per cent of those who left in 1996 had university degrees whereas 30 per cent of those who left in 2001 held university degrees.[64] While the ability to educate its children is important to the innovation process within a province, a province's ability to retain its population once educated is probably more important. Out-migration reduces the capacity of Newfoundland and Labrador to participate in knowledge-based activities. The "brain drain" is real and represents the greatest threat to the knowledge base in Newfoundland and Labrador.

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The Role of Government in a Knowledge-Based Economy

> *As we move into a new information-age economy, the federal role in advancing technology will be increasingly critical. The accelerating pace of technological advance, shorter product cycles and rapid worldwide diffusion of technology mean that many companies are finding it harder to invest in long-term R&D than in the past.*
>
> *Technology and Economic Growth*
> *Producing Real Results for the American People*
> *White House (1995)*

The government has several important roles to play in the knowledge-based economy.[65] For example, in Canada both the federal and provincial governments perform research and development; contract private sector firms or university researchers to undertake targeted research on their behalf; fund grants to researchers in post-secondary education institutions and industry who, in turn, pursue their own research priorities; support initiatives to facilitate university-industry collaboration; administer tax credits for firms undertaking research and development; are responsible for providing core funding to universities and for the support of education generally; implement legislation and regulations that affect firms undertaking research and development – this would include patent protection, drug testing regulations, trade agreements, labour market initiatives, etc.; institute mentoring services for small businesses; design fiscal (including general levels of taxation) and monetary policy that affect the general health of the economy; and develop policies to promote entrepreneurism. Obviously, the government has a significant ability to influence research and development activity, in particular, and developments in the knowledge economy, in general.

The real question is whether there is a legitimate role for government to play in fostering research and development activities within the economy. The short answer is yes, in that the benefits of research and technology spillover from the researcher to other firms in society.[66] A further justification for government intervention is found in the literature reviews provided in David et al (1992) and Martin et al (1996). These studies indicate that government funding of basic research has substantial benefits for industrial performance. In addition, Feldman (2001) finds that government awards provide a signaling effect for subsequent research and development investment by other sources. Doutriaux (2000) and Nimmo and Brennand (1999) report that government programs have led to an increase in the industry-orientation of Canadian university research and, as noted above, enhanced industry-university collaboration should pay dividends in the form of elevated productivity levels.

Another relevant question is: can government simply rely on the tax system to generate the needed research and development activity? While an appropriate fiscal system can help, it may not be sufficient in and of itself.[67] In fact, both the federal and provincial governments provide research and development tax credits.[68] It has been estimated that provincial and federal governments research and development tax credits reduce the after-tax cost of $1 of research and development spending to about $0.52 for large businesses and about $0.48 for small ones.

This compares favourably with most American states, where the after-tax cost of one dollar of research and development spending varies between $0.52 and $0.60.[69]

The Government of Canada has estimated that one dollar of support through the SR&ED tax credit generates approximately $1.38 of additional research and development spending by firms and causes Canadian real income to increase between $20 million and $55 million per annum.[70] Other researchers report varying estimates for the effectiveness of tax credits. For example, using Canadian data, Dagenais, Mohnen and Therrien (1997) report one dollar of extra research and development expenditure per dollar of tax expenditures; Mansfield and Switzer (1985) indicate $0.40 of additional research and development is generated for each dollar of tax forgone in research and development tax incentives for Canadian firms; Bernstein (1986), using Canadian data, reports $0.80 for each dollar forgone tax revenue, but he indicates that this could rise to $1.70 when spillovers are considered; Berger (1992), using data from the United Sates, estimates $1.74 additional research and development per dollar for foregone tax revenue; Hall (1993) finds $2 of additional research and development for every dollar of tax revenue forgone; and Hines (1993) reports $1.2 to $1.90 per dollar of tax revenue. While the results are mixed, Mohnen (1999) suggests that the results indicate research and development "tax incentives are not very effective in stimulating more research and development than the amount of tax revenue foregone." However, Mohnen (1999) does argue that even if the stimulative effects of the tax credit are not as large as people might hope, government support of research and development activity is still justified by the spillover effect of research and development; that is, because the social return exceeds the private return.

In addition to how effective the SR&ED tax credit has been, there have been other concerns raised with this program. These include the lack of timeliness in determining the eligibility of certain activities,[71] the non-eligibility of certain expenditures, the compliance costs and the negative taxable income position of some research and development firms.[72] In fact, some of these concerns are serious enough that not all performers of research and development are using the tax credit programs. For example, according to the Survey of Innovation 1999, about 41 per cent of Newfoundland and Labrador's manufacturers involved in research and development activities used federal or provincial research and development tax credits during the period 1997–99. This compared to 59 per cent for Canada as a whole.[73]

Another general set of concerns about government subsidy programs was raised by Morck and Yeung (2001). They argue that subsidy programs aimed at encouraging innovation within firms are not normally successful. They appear to turn entrepreneurs into grantrepeneurs – that is, firms who are innovative in ways of extracting money from the government.

While, within the context of this paper, it is not possible to provide a detailed assessment of federal programs and agencies that support research and development activity in Canada, a list of the more important programs are:

- Industrial Research Assistance Program (IRAP);[74]
- Technology Partnerships Canada (TPC);[75]
- The Scientific Research and Experimental Development (SR&ED) tax incentive;[76]
- National Research Council (NRC);[77]
- National Centres of Excellence (NCE);[78]
- The Canadian Space Agency (CSA);[79]

- The Natural Sciences and Engineering Research Council of Canada (NSERC);[80]
- The Social Sciences and Humanities Research Council of Canada (SSHRC);[81]
- The Canadian Institute for Health Research (CIHR);[82]
- The Canada Foundation for Innovation (CFI);[83]
- Canada Research Chairs program (CRC);[84]
- Trans-Forum;[85]
- Canadian Technology Network (CTN);[86]
- Strategis;[87]
- Smart Communities;[88]
- Broadband for Rural and Northern Development Pilot Project;[89]
- Atlantic Innovation Fund (AIF).[90]

This discussion of government policy and support concludes with a review of the innovation funding received in Newfoundland and Labrador from select federal programs. This information is provided in Tables 3 and 4 below.

For the five years listed, Newfoundland and Labrador received more than $200 million. With the introduction of the AIF funding in 2001 – 2002, Newfoundland and Labrador's share of federal innovation funding rose from 1.7 per cent to 3.1 per cent. That is, Newfoundland and Labrador appears to be getting more than its per capita share of the federal program considered in Tables 3 and 4. In fact, with the exception of the CFI and CHIR, Newfoundland and Labrador is getting more than its per capita share.

Table 3: Provincial Breakdown of Federal Innovation Funding – Select Programs

	NL	PEI	NS	NB	QUE	ON	MN	SK	AB	BC	CAN
						Millions of Dollars					
IRAP											
1997-98	$3.3	$1.6	$3.7	$3.0	$19.8	$28.4	$2.7	$3.6	$7.7	$13.7	$87.5
1998-99	$3.3	$1.6	$3.7	$3.0	$19.8	$28.4	$2.7	$3.6	$7.7	$13.7	$87.5
1999-00	$3.7	$1.9	$4.1	$4.4	$20.8	$31.0	$3.5	$3.7	$10.1	$14.0	$97.2
2000-01	$3.3	$2.0	$4.3	$3.5	$18.1	$36.2	$2.9	$2.7	$10.7	$12.2	$95.9
2001-02	$3.8	$2.2	$4.7	$3.7	$17.9	$35.0	$2.9	$2.7	$8.6	$14.9	$96.4
NRC											
1997-98	$12.5	$1.8	$12.6	$3.4	$64.5	$291.3	$11.8	$15.2	$8.9	$64.4	$486.3
1998-99	$12.8	$2.7	$13.5	$4.7	$68.2	$303.3	$13.7	$15.4	$12.0	$68.4	$514.8
1999-00	$11.9	$2.2	$16.3	$4.7	$79.2	$303.6	$16.0	$18.2	$11.1	$70.1	$533.3
2000-01	$13.1	$2.2	$21.9	$3.9	$70.0	$343.0	$18.4	$21.7	$11.9	$72.8	$578.9
2001-02	$15.2	$2.5	$22.0	$4.3	$85.2	$359.1	$20.1	$23.7	$14.0	$82.9	$629.2
NSERC											
1997-98	$6.0	$0.5	$13.9	$6.6	$92.9	$144.8	$12.4	$11.2	$41.4	$58.4	$417.1
1998-99	$7.2	$0.6	$13.4	$6.9	$105.0	$170.4	$12.6	$12.5	$48.7	$65.5	$477.1
1999-00	$9.9	$0.6	$17.2	$7.4	$118.9	$180.8	$13.3	$13.7	$52.1	$73.8	$526.1
2000-01	$9.5	$0.8	$16.7	$7.6	$117.5	$188.6	$14.0	$15.1	$56.5	$67.6	$532.9
2001-02	$9.4	$0.8	$18.2	$7.0	$118.0	$185.2	$13.3	$13.2	$55.3	$69.0	$527.6
SSHRC											
1997-98	$0.5	$0.1	$1.9	$0.8	$23.5	$31.9	$2.1	$0.7	$6.7	$11.7	$79.9
1998-99	$0.7	$0.1	$2.1	$0.9	$0.5	$34.5	$1.7	$0.9	$7.1	$12.6	$61.2
1999-00	$2.2	$0.1	$3.3	$1.0	$31.0	$45.3	$2.5	$1.4	$8.6	$16.7	$112.1
2000-01	$2.2	$0.1	$3.7	$1.1	$33.8	$52.8	$3.0	$1.6	$10.8	$17.9	$126.9
2001-02	$2.8	$0.2	$3.8	$1.2	$38.4	$58.2	$3.0	$2.5	$13.6	$18.1	$141.8
CIHR											
1997-98	$1.3	$0.1	$5.4	$0.1	$71.8	$80.8	$7.5	$2.3	$28.2	$19.3	$223.4
1998-99	$1.7	$0.1	$6.0	$0.1	$76.5	$95.8	$8.2	$2.6	$31.7	$22.6	$254.6
1999-00	$1.9	$0.1	$6.7	$0.1	$88.3	$114.4	$8.8	$2.8	$36.0	$24.9	$290.9
2000-01	$2.2	$0.2	$7.6	$0.1	$106.5	$143.9	$9.9	$3.6	$43.4	$27.4	$362.8
2001-02	$3.1	$0.5	$11.5	$0.4	$134.0	$183.0	$14.7	$5.4	$55.0	$42.3	$485.3
CFI											
1997-98	$0.6	$0.0	$0.9	$1.4	$19.2	$21.5	$2.1	$0.3	$5.9	$6.3	$58.0
1998-99	$3.0	$0.2	$8.0	$1.7	$88.6	$172.7	$4.9	$66.2	$30.8	$24.6	$400.7
1999-00	$2.4	$0.5	$6.6	$1.4	$128.2	$153.7	$8.6	$9.2	$21.8	$78.1	$410.5
2000-01	$0.5	$0.2	$2.2	$0.9	$20.9	$36.2	$2.6	$3.2	$9.1	$9.0	$84.8
2001-02	$6.1	$3.8	$8.6	$5.5	$195.0	$227.7	$10.3	$20.2	$106.3	$102.6	$686.1
CRC											
2000-01	$0.0	$0.0	$0.0	$0.3	$3.0	$6.5	$0.6	$0.0	$1.4	$1.5	$13.3
2001-02	$0.3	$0.1	$1.0	$0.9	$15.3	$24.2	$1.7	$1.0	$7.1	$7.9	$59.4
AIF											
2001-02	$45.0	$25.5	$46.6	$37.6							$154.7
Combined											
1997-98	$24.2	$4.0	$38.3	$15.4	$291.6	$598.7	$38.6	$33.3	$98.8	$173.8	$1,352.1
1998-99	$28.7	$5.3	$46.7	$17.2	$358.7	$805.2	$43.9	$101.2	$138.1	$207.4	$1,795.9
1999-00	$32.0	$5.3	$54.3	$18.9	$466.4	$828.9	$52.6	$49.1	$139.6	$277.6	$1,970.2
2000-01	$30.9	$5.6	$56.3	$17.4	$369.8	$807.3	$51.3	$47.8	$143.8	$208.4	$1,795.6
2001-02	$85.8	$35.6	$116.4	$60.6	$603.8	$1,072.4	$66.0	$68.7	$259.9	$337.7	$2,780.5

Table 4: Provincial Shares of Federal Innovation Funding – Select Programs

		NL	PEI	NS	NB	QUE	ON	MN	SK	AB	BC
		Expenditure Shares (Per centage of Canadian Total for Program and Year)									
IRAP	1997-98	3.7%	1.8%	4.2%	3.5%	22.6%	32.5%	3.1%	4.1%	8.8%	15.7%
	1998-99	3.7%	1.8%	4.2%	3.5%	22.6%	32.5%	3.1%	4.1%	8.8%	15.7%
	1999-00	3.8%	2.0%	4.3%	4.5%	21.4%	31.9%	3.6%	3.8%	10.3%	14.4%
	2000-01	3.4%	2.1%	4.4%	3.6%	18.9%	37.7%	3.1%	2.8%	11.1%	12.8%
	2001-02	4.0%	2.3%	4.9%	3.9%	18.5%	36.3%	3.1%	2.8%	8.9%	15.4%
NRC	1997-98	2.6%	0.4%	2.6%	0.7%	13.3%	59.9%	2.4%	3.1%	1.8%	13.2%
	1998-99	2.5%	0.5%	2.6%	0.9%	13.2%	58.9%	2.7%	3.0%	2.3%	13.3%
	1999-00	2.2%	0.4%	3.1%	0.9%	14.8%	56.9%	3.0%	3.4%	2.1%	13.2%
	2000-01	2.3%	0.4%	3.8%	0.7%	12.1%	59.3%	3.2%	3.7%	2.0%	12.6%
	2001-02	2.4%	0.4%	3.5%	0.7%	13.5%	57.1%	3.2%	3.8%	2.2%	13.2%
NSERC	1997-98	1.4%	0.1%	3.3%	1.6%	22.3%	34.7%	3.0%	2.7%	9.9%	14.0%
	1998-99	1.5%	0.1%	2.8%	1.4%	22.0%	35.7%	2.6%	2.6%	10.2%	13.7%
	1999-00	1.9%	0.1%	3.3%	1.4%	22.6%	34.4%	2.5%	2.6%	9.9%	14.0%
	2000-01	1.8%	0.1%	3.1%	1.4%	22.1%	35.4%	2.6%	2.8%	10.6%	12.7%
	2001-02	1.8%	0.2%	3.5%	1.3%	22.4%	35.1%	2.5%	2.5%	10.5%	13.1%
SSHRC	1997-98	0.6%	0.1%	2.3%	1.0%	29.4%	39.9%	2.6%	0.9%	8.4%	14.7%
	1998-99	1.1%	0.1%	3.5%	1.4%	0.9%	56.4%	2.8%	1.5%	11.7%	20.6%
	1999-00	2.0%	0.1%	3.0%	0.9%	27.6%	40.4%	2.2%	1.3%	7.6%	14.9%
	2000-01	1.8%	0.1%	2.9%	0.8%	26.6%	41.6%	2.4%	1.2%	8.5%	14.1%
	2001-02	2.0%	0.1%	2.7%	0.8%	27.1%	41.0%	2.1%	1.8%	9.6%	12.7%
CIHR	1997-98	0.6%	0.0%	2.4%	0.0%	32.2%	36.2%	3.4%	1.0%	12.6%	8.6%
	1998-99	0.7%	0.0%	2.4%	0.0%	30.1%	37.6%	3.2%	1.0%	12.5%	8.9%
	1999-00	0.6%	0.0%	2.3%	0.0%	30.3%	39.3%	3.0%	1.0%	12.4%	8.6%
	2000-01	0.6%	0.1%	2.1%	0.0%	29.4%	39.7%	2.7%	1.0%	12.0%	7.6%
	2001-02	0.6%	0.1%	2.4%	0.1%	27.6%	37.7%	3.0%	1.1%	11.3%	8.7%
CFI	1997-98	1.0%	0.0%	1.6%	2.5%	33.0%	37.0%	3.5%	0.5%	10.1%	10.8%
	1998-99	0.7%	0.1%	2.0%	0.4%	22.1%	43.1%	1.2%	16.5%	7.7%	6.1%
	1999-00	0.6%	0.1%	1.6%	0.3%	31.2%	37.4%	2.1%	2.2%	5.3%	19.0%
	2000-01	0.6%	0.3%	2.6%	1.1%	24.7%	42.7%	3.1%	3.7%	10.8%	10.6%
	2001-02	0.9%	0.5%	1.3%	0.8%	28.4%	33.2%	1.5%	2.9%	15.5%	15.0%
CRC	2000-01	0.0%	0.0%	0.0%	2.3%	22.6%	48.8%	4.1%	0.0%	10.7%	11.5%
	2001-02	0.5%	0.1%	1.6%	1.5%	25.8%	40.7%	2.8%	1.7%	11.9%	13.3%
AIF	2001-02	29.1%	16.5%	30.1%	24.3%						
Combined	1997-98	1.8%	0.3%	2.8%	1.1%	21.6%	44.3%	2.9%	2.5%	7.3%	12.9%
	1998-99	1.6%	0.3%	2.6%	1.0%	20.0%	44.8%	2.4%	5.6%	7.7%	11.5%
	1999-00	1.6%	0.3%	2.8%	1.0%	23.7%	42.1%	2.7%	2.5%	7.1%	14.1%
	2000-01	1.7%	0.3%	3.1%	1.0%	20.6%	45.0%	2.9%	2.7%	8.0%	11.6%
	2001-02	3.1%	1.3%	4.2%	2.2%	21.7%	38.6%	2.4%	2.5%	9.3%	12.1%

By 2002, the CFI-funded projects were worth $1.6 billion in 10 provinces. Newfoundland and Labrador received less than one per cent of the total dollar value awarded and received $12 million. The list of the funded projects is provided in Appendix B.

The objective of the AIF is to accelerate economic development in Atlantic Canada by stimulating the knowledge-based economy. Forty-seven research and development projects, worth $155 million, were funded through the Atlantic Innovation Fund in 2002. Of the total, Newfoundland and Labrador and Nova Scotia captured the largest share of the funding. Each was awarded $45 million or 29 per cent of the $155 million. A total of $36.7 million was awarded to the non-commercial sector and $8.3 million to the commercial sector in Newfoundland and Labrador. As a percentage of total funding, Newfoundland and Labrador's commercial sector received 18 per cent of the total funding that was awarded to Newfoundland and Labrador. The commercial sector of the other three Atlantic Provinces received a higher per centage, with receiving New Brunswick 35 per cent, Nova Scotia 27 per cent and Prince Edward Island 24 per cent. The list of funded projects is provided in Appendix C.

Conclusion and Policy Recommendations[91]

Knowledge, research and development and innovation activities are significant determinants of the productivity, competitiveness, economic growth and well being that can be achieved by Newfoundland and Labrador. Unfortunately, the province's indicators of knowledge capacity and performance are not encouraging. In particular, research and development activity in the business sector needs to be improved, as does the general level of research and development within the province. While local businesses can benefit via the diffusion of technology from elsewhere, the benefits that result from adopting research and development performed in other jurisdictions is tied to the capacity of the receptor companies to absorb that research and development. The absorptive capacity of businesses is tied directly to their own capacity to undertake research and development. This, of course, magnifies the problems associated with low levels of research and development performed by Newfoundland and Labrador's business sector because the province cannot simply depend on diffusion to overcome all of the problems associated with low levels of domestic research and development.

The Internet and advances in ICT perform an important enabling role in enhancing productivity and growth. Broadband access to the Internet in rural Newfoundland and Labrador needs to be expanded to enable a fuller participation of households and businesses in the knowledge economy. It is also necessary to recognize that Internet and developments in ICT can help, but they cannot be expected to overcome the economic reality of geography and location.

It will still take a concerted effort on the part of government, business, labour and the university to help identify the strengths of the Newfoundland and Labrador economy that offer the best potential for development and progress within the knowledge economy. In particular, general improvements in the economy, which provide real economic opportunities for Newfoundland and Labrador's recent graduates, offer one of the best means of overcoming problems associated with the "brain drain". As well, general improvements in the economy will enable the government to lower taxes in the economy, making Newfoundland and Labrador a more attractive place to invest. Furthermore, general improvements in the educational system is probably the best investment that government can make to improve the long-term position of Newfoundland and Labrador in the Canadian economy.

The university has a special and extremely important role to play in the knowledge economy. It has to be competitive in terms of research and the quality of faculty available to train our students and address local issues. This may require enhanced core funding to enable the university to pay competitive salaries; implementation of provincial grant programs to allow university researchers to access national funds that have matching requirements; and an increase in the faculty complement to enable the university to acquire a critical mass of researchers in targeted areas. As well, there needs to be an improvement in the level of collaboration between Memorial University and the private sector. Finally, more of its intellectual capital ought to be focused on issues that are important to the local economy.

The federal government has an important role to play in the direct funding of research and development through the granting councils. The eligibility requirement attached to innovation programs and tax credits need to be re-evaluated and revised to eliminate subtle biases that reduce the ability of Newfoundland and Labrador to access a larger share of innovation funds.

The provincial government needs a comprehensive and coherent policy that deals effectively with any opportunity available through the knowledge economy. It needs to put in place policies that maximize opportunities within Newfoundland and Labrador for its young people. This should help mitigate the significance of the brain drain.

In addition to these general concerns, we offer the following specific policy recommendations to optimize the benefits flowing from knowledge-based activities in the Newfoundland and Labrador economy:

1. Initiatives should be put in place to improve the degree of collaboration between Memorial University, businesses, labour and the provincial and federal governments. For example, this would require:
    - Memorial University to implement an incentive structure for faculty members to collaborate with the other stakeholders and to address problems that are particularly important for the local economy;
    - Joint research forums between university faculty members and researchers from the other stakeholder groups;
    - Increased core funding for Memorial University to enable it to offer competitive salaries with other Canadian universities in order to attract faculty that are of the highest quality; and,
    - Creating and funding a research institute whose mandate is to research issues related to exploiting opportunities created by science, technology and innovation and development relevant indicators to measure Newfoundland and Labrador's progress in the knowledge economy.
2. The federal government should improve the eligibility criteria utilized for its investment tax credit so that more local companies can qualify for the tax credit. As well, innovation funding programs have to be designed so that provinces such as Newfoundland and Labrador capture a greater share of these funds – this would include the CFI, Canada Research Chairs program and funding from the three granting councils. Increase funding to the major granting councils, with specific direction to implement grant competitions and programs that have regionally-based funding targets.
3. The provincial government needs to:
    - Implement innovative funding initiatives to enhance the retention of high-knowledge workers who are in short supply. For example, the shortage of doctors might be helped if the medical school tuition was raised to be equivalent to cost-plus 10 per cent and allowing medical students to apply for loans equal to this amount, under the condition that 20 per cent of the loan is retroactively converted into a scholarship for each year that the new doctor practices in Newfoundland and Labrador after graduation;
    - Stop the out-migration of knowledge workers. This might require the introduction of education subsidies or tax incentives designed to keep knowledge workers in the province;
    - Create an explicit strategy designed to take advantage of opportunities created by the knowledge economy;
    - Market the positive aspects of knowledge-based activities in schools;

- Encourage life-long learning through education credits;
- Provide subsidies to firms who introduce knowledge-based learning activities; and,
- Target knowledge-based occupations and encourage immigration of outside knowledge-workers from outside of the province or outside of the country.

4. Businesses and government need to examine innovative financing mechanisms that might be adopted to facilitate enhanced research and development within the business sector. This, for example, might include venture capital funds that are targeted at knowledge-based activities.

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Endnotes

1 For example, Blinder (2000) simply asserts that technology is the primary driver of productivity gains, Government of Canada (2002) states that "knowledge is the main source of competitive advantage", OECD (2000) reports that "innovation and technical change are…among the most important drivers of economic growth", Wolfe and Salter (1997) suggests that "knowledge is becoming the most important factor contributing to the health of the economy", the Council of Atlantic Premiers (2001) notes that "research and innovation is a key driving force in the growth of the global knowledge industry", Government of Canada (1994b) reports that "Knowledge is becoming the most important factor contributing to the health of the economy" and Feldman et al (2002) declare that "technology drives economic growth".

2 Government of Canada (2002a). OECD (2000) also noted that: "Available evidence suggest that interaction between the science system and the business sector is more prominent than in the past and that in many fields, technological innovation makes more intensive use of scientific knowledge."

3 As the following studies demonstrate, more than 50 per cent of the growth in North America in the last 100 years can be traced to technological progress: Abramovitz (1956), Denison (1962), Denison, E (1979), Denison (1985), Jarbow and Atkinson (1998), Jorgenson and Griliches (1972), Jorgenson, Gallop and Fraumeni (1987), Kendrick (1961), Kendrick (1973), Kuznets, (1971), Solow, (1957). As well, Ten Raa and Mohnen (1999) demonstrate that for Canada, productivity growth in the 1960s and 1970s was explained by technical change, but changes in the terms of trade in the late 1980s accounted for productivity in the 1980s.

4 Examples of this new theoretical approach can be found in Romer (1990), Romer (1994), Grossman and Helpman (1991) and Aghion and Howitt (1995).

5 In the context of economics, Globerman (2000) notes that new processes lead to reductions in the costs of production and new products, with their corresponding new or enhanced attributes at similar or lower prices, improving the welfare of consumers. Government of Canada (2001) asserts that "Unquestionably, innovation is the link between science and technology (S&T) and both long-term economic growth and quality of life." As well, Locke and Lynch (2001) find that higher investments in research and development within an area generate improved levels of productivity for that area and Baldwin et al (2000) demonstrated that Canadian firms who perform research and development are four times more likely to introduce an innovation. Other studies that show the link between research and development and productivity are: Centre for the Study of Living Standards (1998), Coe and Helpman (1995), Kao et al (1999), Crisculo and Haskel (2002) and Visco (2000).

6 Government of Canada (2002) suggests that "innovation means greater competitiveness in markets that are increasingly global. Canada's most productive industries have better productivity performance, grow faster, and generate higher quality, higher paying jobs." As well, Jones and Pandya (1996) suggest that competitiveness at the firm level is tied to "the

capacity of firms to innovate." Morck and Yeung (2001) point out that innovation bestows a competitive advantage on firms by allowing them to develop cheaper ways of producing existing goods so that they can make extra profits on their existing output or develop new and better products which can be sold at a profit because, for a period of time, they alone are the only producer of these new products. In both cases, the basic idea is that innovation gives the innovative firms a degree of monopoly power.

7 As a further illustration, consider that Orr (2000) demonstrated that the differences in GDP per capita across provinces are explained primarily by variations in productivity exhibited by these provinces. In other words, the differences in the standards of living across jurisdictions can be explained by differences in productivity and differences in productivity can be traced to differences in both the research and development activities and the state of innovation achieved by these jurisdictions. As well, Morck and Yeung (2000) established empirically that an improvement in innovation within a country translates into an increase in its standard of living and Schacht (1996), using international statistics, illustrates the strong inverse relationship between productivity and unemployment.

8 OECD (2000) finds that "countries with larger increases in the intensity of business R&D to GDP and in the share of business R&D in total R&D … appear to have experienced a pick-up in productivity growth in the 1990s." The connection between research and development by the industrial sector and innovation in Canada was also noted in Government of Canada (1999) and Globerman (2000). As well, Lejour and Nahuis (2000) find that research and development activity reinforces the benefits countries gain from trade liberalization.

9 Research and development and the knowledge acquired from the same have a snowball effect. Specifically, the acquisition of knowledge facilitates and promotes the development of new knowledge, further increasing productivity in an area. These points were emphasized by an OECD (1991) report, which stated: *technical change does not occur randomly for two main reasons: (1) in spite of considerable variations with regard to specific innovations, the directions of technical change are often defined by the state-of-the-art technologies already in use, and (2) the probability of technological advances by firms, organizations and even countries is, among other things, a function of the technological levels already achieved by them. In other words,… technical change is to a large extent a cumulative activity*.

10 The fact that the social return on research and development is higher than the private return is demonstrated by: Bernstein (1996), Bernstein and Nadiri (1988), Bernstein (1989), Bernstein and Nadiri (1991), Goto and Suzuki (1989), Griffith (2000), Griliches (1995), Funke (2000), Mansfield et al (1977), Mohnene (1992), Nadiri, (1993), OECD (2000), Scherer (1982), Scherer (1984), Sveilkauskas, (1981), and Terleckyi, (1974).

11 Public goods are characterized as being non-excludable and non-rival. It is well established in the public finance literature that goods with these characteristics will be provided at inefficiently low levels, if at all, by the private sector.

12 Griffith (2000) notes that the difference between the social return and the private return is "one of the main justifications for government subsidies".

[13] However, that study does recognize that some of the changes observed in innovation were outside of the developments that have occurred in the ICT sector. It also acknowledges that "some of the impacts of ICT would probably not have occurred without broader changes in the innovation system."

[14] Polese et al (2002), for example, noted: "The arrival of IT has raised hopes that the tyranny of distance will be reduced in the future, opening up new perspectives for regions that have hitherto been handicapped by their peripheral location."

[15] Consider, for example, how Dell computers are now bought over the Internet. A customer accesses their web site and indicates the specification of the computer that he/she would like to purchase. It is then built and sent to the customer. In this model inventory costs are at a minimum, resulting in both storage cost savings and lower interest costs associated with carrying large inventories.

[16] By way of illustration, Dholakia et al (2001) note that the average cost of a banking transaction falls from $1.27 in a branch to $0.01 on the Internet and Litan and Rivlan (2001) highlight the fact that the cost of processing health insurance claims can fall from $10-15 for paper to two to four cents with web-based processors.

[17] Litan and Rivlan (2001) highlight the benefitd derived by the trucking industry from web-based technology because there is a better match between supplier and demanders and the trucking companies have an enhanced facility to track or reroute shipments to better satisfy their customers' needs.

[18] There is a difference between knowledge and information, which is tied to the distinction between tacit and codified knowledge. The implication of this distinction is dealt with below.

[19] Polese et al (2002) find that advances and ICT and the Internet, rather than reducing the need to meet, increase the need for face-to-face meeting in the knowledge-based economy.

[20] Statistics Canada Establishment Accounts.

[21] Statistics Canada Establishment Accounts.

[22] RBC Financial Group, Canadian Families and the Internet, Jan 23, 2002, www.rbc.com, reports that according to IPSOS-Reid Inter@ctive Reid Report, Q3, 2001, 16 per cent of Canadian adults had Internet access in 1996 and that this has grown to nearly 60 per cent today.

[23] RBC, p.11.

[24] Statistics Canada Household Internet Usage Surveys 1997-2000.

[25] The characteristics that were held constant were family size, employment status, household age and computer ownership.

[26] Canadian Federation of Independent Business, E-Business Update, Internet Use Among SMEs.

[27] Source: Compiled from Maps of Broadband Distribution in Canada, Industry Canada. http://smartcommunities.ic.gc.ca/bbmaps/canada/map.htm. 2001

[28] The access rate is defined as the total population with broadband access divided by the total population of all the communities in each province.

[29] Adding Labrador's two cable communities.

[30] See Lynch and Locke (2002).

[31] While it is surprising that an increase in access in rural Newfoundland and Labrador has not translated into increased household Internet usage, we do not currently have an explanation for this phenomenon. However, research that we are undertaking in the summer of 2003 should shed some insights on to this issue.

[32] See footnote 10 above.

[33] Griffith (2000) notes that the social rate of return can be as high as 100 per cent. Whether it reaches this level is not the important issue. All that really matters is that the social return exceed the private return as motivation for government intervention and there is a substantial body of literature that demonstrates that this is the case. See, for example, Feldman (2001) or Martin et al (1996).

[34] As Griffith (2000) suggests, the optimal subsidy to research and development would equate private and social rates of return. Since the firm is picking up a lower share of the costs of research and development at the margin, they have an incentive to increase the level of research and development activity. Consequently, if the subsidy is set appropriately, an optimal amount of research and development is performed.

[35] Funke (2001) indicates that the international evidence demonstrates the existence of spillovers across geographic boundaries.

[36] The absorptive capacity of firms, as described in Cohen and Levinthal (1989) and (1990), relates to its ability to identify and use relative external knowledge for its own activity and this appears to be tied to their own research and development intensity.

[37] Mohnen and Hoareau (2002) and Griffith et al (2000) provide empirical support for the absorptive capacity hypothesis. As well, Mansfield et al (1981) find that there are substantial costs associated with copying innovations developed by others.

[38] Griffith (2000) highlights the empirical support for the dual role of research and development – it stimulates innovation and facilitates the adoption of existing technology.

[39] The crowding out occurs because scientists and engineers are in inelastic supply and, as such, subsidies simultaneously increase the demand for their services and increase their rate of remuneration. Consequently, undertaking research and development becomes more expensive and private sector firms reduce the level of research and development that they would otherwise undertake. That is, private sector research and development is crowded out.

[40] See, for example, Jaffe (1997), Trajtenberg (2001), David, Hall and Toole (2000) and Feldman (2001).

41 It is interesting to note that these figures relate to research and development undertaken by the federal government. A slightly different picture emerges when the research and development funded by the federal government is considered. For example, the federal government funded $3.2 billion in research and development across Canada in 1999 – Ontario received $1.6 billion and Newfoundland and Labrador received $48 million. This translates into 0.4 per cent of GDP in Newfoundland and Labrador and Ontario and about 0.3 per cent Canada-wide. In per capita terms, this represents $88 in Newfoundland and Labrador, $143 in Ontario and $106 Canada-wide.

42 Of course, the number of patents issued in an area is not perfectly correlated with the amount of innovation activities taking place within that area. For instance, many patents never actually translate into new products or new processes

43 Feldman, Fuller, Bercovitz and Burton (2001) argue that, with the Internet and advances in ICT, information is now more easily collected, stored, processed, accessed, communicated and used.

44 An implication of this is that people have to take time to have the tacit aspects of knowledge explained. This means that imitation of research and development can be costly and will have implications for whether research and development imparts knowledge that is a pure public good. This point was reinforced by Wolfe and Salter (1997) when they pointed out that the ability to use information almost always requires knowledge. Specifically, "individuals and organizations require a complex set of skills and must expend considerable resources both to absorb and understand information. Without these investments, firms would be unable to make use of the information available to them. In this respect, information only becomes codified knowledge (and therefore valuable and useful) when users have the skills and capabilities to make sense of it."

45 Locke and Lynch (2002) present data on the concentration of R&D expenditures in Canada and Feldman et al (2002) indicate that R&D activity in the US is highly concentrated in a small number of states.

46 Feldman et al (2001) identify these areas as knowledge clusters and they argue that there is a direct relationship between the propensity for industries to concentrate geographically and the knowledge intensity of their activity.

47 Martin and Trudeau (1998) have, for example, estimated that Canadian university research contributes $15.5 billion in GDP to the Canadian economy and accounts for between 150,000 and 200,000 jobs per annum. Moreover, they link knowledge clusters in Ottawa, Montreal and Saskatoon to local universities.

48 See, for example, Mansfield and Lee (1996) who demonstrate that firms located close to academic research centers have an advantage over others; Feldman (2001) says exchanges between university and industry scientists enhance innovation; Cohen (1995) reports that a significant determinant of innovation activity is the geographic proximity of the firm to basic science; Jones and Pandya (1996) consider the impact of universities on innovation in Ireland, Association of Atlantic Universities (1999) highlights the connection between a region's economic competitiveness and the academic competitiveness of its universities; Government of Canada (1999) specifies the role of Canadian universities in strengthening

Canada's innovation capacity and productivity; Morck and Yeung (2001) discuss the role that education and human capital have in influencing the pace of innovation; Wolfe (1998) notes that firms located close to centers of academic research have an advantage over other firms; and OECD (2000) acknowledges the role that scientific institutions and human capital play in the process of innovation.

49 For example, Feldman and Desrochers (forthcoming) note that "despite substantial academic achievements, Johns Hopkins provides an example of a university that has had little direct effect on its regional economy."

50 See, for example, Feldman and Desrochers (forthcoming), Jones and Pandya (1996), OECD (2000), Doutriaux (2000b), and Locke et al (2002) for illustrations of why universities might not have the economic development impacts that are possible.

51 Gu and Whewell (1999) note that "the biggest barrier to university-industry collaboration is the culture gap… The culture of university research has a long-term, generic perspective that is important. The culture of industry fosters a shorter term view of knowledge, focusing on solving a particular technical problem in the near future."

52 For more detail on the types of collaborations that have been considered in the literature, see Feldman (2001), Globerman (2000), Martin and Trudeau (1998) and Doutriaux and Barker (1995).

53 Gu and Whewell (1999), reporting on a 1995 NSERC and Conference board survey, indicate that 60 per cent of industry respondents and 88 per cent of university respondent agreed that contracting out remains the most common form of research collaboration between university and industry.

54 Faulkner and Senker (1995) indicate that personal relationships between scientists in industry and the public sector are one of the best ways to facilitate successful collaboration, which builds understanding and trust and leads to long-term contractual relationships. Doutriaux and Barker (1995) also emphasize that personal relations "are often forerunners of direct technology-transfer activities involving the licensing of patents or other intellectual property to industry, or the creation of new business through spin-off companies."

55 See, for example, Doutriaux (2000) and Doutriaux and Barker (1995).

56 Beaudin and Breau (2001) note that out-migration of skilled personnel is a very real problem for Atlantic Canada.

57 Association of Atlantic Universities (2002).

58 The relationship between general education and growth was raised by one of the referees. Mankew et al (1992), Barro (1991), Krueger and Lindhal (2001), Hanushek and Kimko (2000), Temple (2001) and Frantzen (2000) report that improved education levels lead to higher levels of economic growth. On the other hand, Islam (1995) and Caselli et al (1996) did not find this relationship.

59 The following analysis draws on Locke and Lynch (2002).

60 Royal Bank of Canada. Interprovincial Mobility of Highly Skilled Workers. 1999.

[61] The flows of university graduates was measured as the share of the total population with university degrees. Knowledge workers were defined to include workers from the following occupations: management, business, finance, administrative, natural and applied sciences and health. Source: See footnote 60 above.

[62] Source: Statistics Canada, Demographic Division, Economics Statistics Branch. Newfoundland Statistical Agency

[63] See Locke and Lynch (2002).

[64] Source: Newfoundland Statistical Agency. Survey of Out-Migrants: Background Report. October 2002

[65] Griffith (2000) and Visco (2000) list some of the ways that government promotes innovation.

[66] White House (1995) highlights the role of spillovers as a rationale for government intervention in promoting research and development in the private sector. Government of Canada (2001a) also acknowledges that it funds private sector research and development for the same reason.

[67] This point was emphasized in a recent study by the Centre for the Study of Living Standards (1998) where it was suggested: "*the potential for lower corporate taxes to generate additional investment in the Canadian economy appears limited. First, the corporate tax burden in Canada is already low from an international perspective. According to OECD (1995) figures, the burden of corporate income taxes in Canada, which represents 1.75 per cent of GDP, is about two-thirds the OECD average of 2.64 per cent of GDP. Second, Canada's corporate tax burden is competitive with that of our major trading partner, the United States.*"

[68] A description of these tax credits can be found in Warda (1999), Government of Canada (1997), and Government of Canada (2001).

[69] Government of Canada (2002b).

[70] Government of Canada (2001).

[71] Government of Canada (2001).

[72] Government of Canada (2002b).

[73] Government of Canada (2002b).

[74] IRAP helps small and medium-sized enterprises (SMEs) turn good ideas into commercially viable products and services. … IRAP attempts to increase the innovation capabilities of SMEs. The Government of Canada (2001), while concerned with the detail and due diligence in reporting results and describing reasons why government funding is required, considers IRAP to be one of the most effective programs among the federal S&T policy instruments and felt that the federal government should increase the funds going to this program.

75 TPC is an investment fund through which the federal government provides repayable contributions towards research conducted in Canadian companies in areas of strategic economic importance. By partnering with research companies and altering the time profile of a project's cash flow, TPC encourages Canadian private-sector investment in maintaining and growing the technology base and capabilities of Canadian industry. Government of Canada (2001) was concerned that two-thirds of TPC funds are targeted at aerospace and defense and one-third for enabling and environmental technologies. However, it felt that the federal government should increase flowing to this program. Beaudin and Breau (2001) express concerns about the low level of funding to Atlantic Canadian firms under the TPC program.

76 The SR&ED tax incentive program offers individuals, corporations and partnerships a tax deduction of up to 100 per cent of qualified current scientific research and experimental development expenditures and eligible capital expenditures. The program allows eligible firms to offset tax owing, and individuals and SMEs may qualify for a cash refund.

77 Government of Canada (2001) describes the National Research Council of Canada (NRC) as an agency whose vision is to be a leader in the development of the knowledge-based economy through science and technology. The Council operates a network of research laboratories that can collectively boast a wealth of knowledge, expertise and capability of substantial value to Canadian industry. The NRC tries to transfers technologies developed in-house to Canadian companies with the capacity to develop commercial applications that benefit the Canadian economy as a whole and they undertake collaborative research with Canadian companies. Canadian firms are thus able to have access to state-of-the-art facilities that would otherwise be unavailable to them. While the NRC does carry out basic research and development, its principal activity today is bridging the gap, which involves working in partnership with other players – large and small enterprises, universities and other government labs – to not only develop technology but also to translate that technology into products for the marketplace.

78 The Networks of Centres of Excellences (NCE) program is administered jointly by the three federal granting councils and Industry Canada and it provides a mechanism for bringing together researchers from universities, the private sector and government – often across a number of disciplines – to address research issues of common concern that have economic potential.

79 The Canadian Space Agency (CSA), as described in Government of Canada (2001), has pursued a mission committed to leading the development and application of space knowledge for the benefit of Canadians and humanity.

80 NSERC supports research in universities and colleges, research training of scientists and engineers, and research-based innovation. The Council promotes excellence in intellectual creativity in both the generation and use of new knowledge, and it works to provide the largest possible number of Canadians with leading-edge knowledge and skills. NSERC fulfills this mission by awarding scholarships and research grants through peer-reviewed competition and by building partnerships among universities, colleges, governments and the private sector.

81 SSHRC is the national agency responsible for supporting university-based research in the social sciences and humanities. SSHRC funds basic research – that is, targeted research on issues of national importance – the training of highly qualified personnel and the broad dissemination of knowledge for the benefit of Canadians. Its programs and strategies promote research excellences, innovation, productivity and partnerships with users of research in public, private and community sectors.

82 The CIHR is the federal agency with primary responsibility for funding, promoting and sustaining basic, applied and clinical research in the health sector. Its mandate spans everything from basic to fundamental laboratory research right up to social sciences as it pertains to health, health services and research. More specifically, its objective is to excel, according to internationally accepted standards of science excellence, in the creation of new knowledge and its translation into improved health for Canadians, more effective health services and products and a strengthened Canadian health care system.

83 The Canada Foundation for Innovation (CFI) is an independent corporation whose mandate is to strengthen the research infrastructure at Canadian universities, colleges, research hospitals and other not-for-profit institutions to enable them to carry out world-class research and technology development. According to Government of Canada (2001), by investing together with other funding partners from the public, private and voluntary sectors, the CFI helps to ensure that Canadian researchers will have access to state-of-the-art equipment and facilities. The CFI programs are designed to: build Canada's capacity for innovation; attract and retain highly skilled research personnel in Canada; strengthen research training of young Canadians for the knowledge economy; promote networking; collaboration and multidisciplinary approaches to problem-solving among researchers; and ensure the optimal use of research infrastructure within and among Canadian institutions. It should also be noted that Beaudin and Breau (2001) have raised a concern about the low level of funding received by Atlantic Canada under the CFI program.

84 Under the Canada Research Chairs program, new research positions were created to strengthen degree-granting institutions across Canada – from large universities with research strengths across a variety of disciplines to smaller institutions with more focused research capabilities. The program's key objective is to encourage the building of a critical mass of world-class researchers in order to help Canadian universities achieve research excellence.

85 Doutriaux (2000) explains that Trans-Forum, launched in 1994 by Industry Canada was "an Internet-based communication and information service which links the industry liaison offices of universities, affiliated research institutes, colleges, technical institutes and centres of excellence across Canada. Its purpose is to enhance technology and expertise transfer from higher education to Canadian businesses…"

86 Doutriaux (2000) reports that The Canadian Technology Network (CTN), launched in 1994 and maintained by the National Research Council of Canada (NRC), "links federal and provincial government labs and agencies, universities, community colleges, industry associations, technology centres and economic development agencies."

[87] Doutriaux (2002) noted that in 1996 Industry Canada launched Strategis, which is a very comprehensive Internet site for Canadian businesses with detailed information on consumers, companies, business support and financing, trade and investment, technology and innovation. It provides links to a vast array of public sector and private sector resources and contracts directly relevant to established firms and start-ups, and for technology commercialization.

[88] According to their website www.smartcommunities.ca, the Smart Communities program is an Industry Canada program which is designed to stimulate the development and integration of information and communications technologies in new and innovative ways to enrich Canadian communities socially, culturally and economically.

[89] As indicated on their website www.broadband.gc.ca, this Industry Canada program provides funding to publicly available broadband access to Canadian communities, with priority given to First Nations, northern, remote and rural communities which are currently unserved by DSL or cable modem services.

[90] The AIF program, administered under ACOA, is designed to: (1) increase activity in and to build capacity for innovation, research and development (R&D) which leads to technologies, products, processes or services which contribute to economic growth in Atlantic Canada; (2) increase the capacity for commercialization of R&D outputs; (3) strengthen the region's innovation capacity by supporting research, development, and commercialization partnerships and alliances among private sector firms, universities, research institutions and other organizations in the Atlantic system of innovation, and to increase their critical mass; and (4) maximize benefits from the national R&D programs.

[91] It is important that we acknowledge that one of the anonymous referees perceived a potential conflict of interest associated with a paper written by Memorial University faculty members when Memorial University may benefit from the recommendations contained in this report. In response to this concern, we hope that the information contained in this report does benefit both Memorial University and Newfoundland and Labrador. However, since there is no direct personal benefit to be derived by the authors from general improvements in the university or the economy, we do not feel that there is a conflict of interest, perceived or real. Moreover, we wish to state that all recommendations and information provided in this report are substantiated by the evidence available in the literature and were not influenced by our institutional affiliation.

[92] This list of innovation activities was taken from the information provided in Association of Atlantic Universities (2002).

[93] http://www.acoa.ca/e/financial/aif/prolist.shtml

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Appendix A

Innovation Activities Taking Place at Memorial University[92]

- Memorial University is home to the Advanced Computation and Visualization Centre (CVC) – the most powerful research computer system in Atlantic Canada gives researchers access to parallel computing and high-end graphics capabilities. This is useful for numerical modeling and simulation which is an emerging and increasingly popular way for scientists to visualize complex processes or structures.
- Memorial University has expertise in GIS and remote sensing in coastal regions. Its Geographical and Information and Digital Analysis Labaratory (GEOIDAL) has researched the analysis of remotely sensed data for coastal studies and the integration of satellite data and terrain data for terrain analysis.
- The impact and reach of biotechnology is being enhanced through partnerships with BioEast, the provincial biotechnology organization; through linkages to the growing private sector through Seabright Corporation; and through greater collaboration with regional research institutions such as the National Research Council's Institute of Marine Biosciences.
- In July 2002, the Ocean Sciences Centre received AIF support for biotechnology research to investigate and improve the mechanisms of disease resistance in Atlantic Salmon.
- GeoSpatial Research Facility for Terrestrial Ecosystems.
- Department of Chemistry has research programs in fuel cells, nanotechnology (such as molecular magnets, switches and electronics), and novel photochemical devices for artificial photosynthetic applications. The fuel cell research is support by NSERC and Canadian and US companies and has filed for patents related to this technology.
- The Department of Physics and Physical Oceanography has received CFI funding towards the development of a state-of-the art laboratory to study properties of porous semiconductor materials.
- Research at the Centre for Cold Ocean Resources Engineering (C-CORE) includes remote sensing target direction, shore-based ground wave radar technology used for long-range detection of ice hazards, and Coastal Ocean Dynamics Applications Radar (CODAR). C-CORE is also the site of Canada's largest centrifuge facility.
- The Ocean Engineering Research Centre (OERC) is involved in research and development, including consulting services for offshore and shipbuilding industries, scale model experiments, numerical modeling, software development and structural testing.
- J.I. Clark Chair of Intelligent Systems for Operations in Harsh Environments. This Chair builds upon Memorial's strengths in robotics and intelligent control systems for the mining, oil and gas and aquaculture industries.
- Memorial, in collaboration with the National Research Centre's Institute for Marine Dynamics is involved in research on autonomous underwater vehicles.
- Canada Research Chair in petroleum geoscience.

- Petro-Canada Chair in applied seismology.
- Decisionarium – a 3D visualization centre used for imaging of geological structures, and modeling and visualization of hydrodynamic flows.
- The Anakin Project – an attempt to make it easier for health professions in remote locations to update their skills in neonatal resuscitation methods through mechatronics, the science of integrating electronic devices into mechanical ones.
- Telemedicine Centre – involved in research in the use of interactive communications technologies to supplement health and education in remote areas.
- The Faculty of Medicine, through a new web portal – RuralMDcme.ca – offers online courses to rural physicians.
- The Telemedicine Centre, the Division of Educational Technology and the Telemedicine and Education Technology Resource Agency are conducting research on the use of interactive communications technologies to supplement health and education in rural and remote areas.
- Electronic Medicine Strategy – recently received AIF funding to support an initiative to design, develop and deliver online professional development training tools and resources for physicians.
- Hubert W. Kelly Chair in Youth-focused Technological Entrepreneurship.
- SSHRC strategic grant studying the challenges and opportunity of the knowledge-based economy in Newfoundland and Labrador.
- Memorial University is currently involved with more than 230 research grants and contracts with Canadian and foreign firms.
- GENESIS Group is involved in transferring university research to industry and to the marketplace.
- Examples of successful commercialization are: novel gene discovered by Faculty of Medicine which may have potential as a small molecule blocker; Population Genetics Partnership Initiative, Nova Lipids, and A/F Protein.

Appendix B
Projects Funded in Newfoundland and Labrador Under the Canadian Foundation for Innovation:

- GeoSpatial Research Facility for Terrestrial Ecosystems ($670,060).
- Applied fisheries technology research to develop more effective selectivity devices and strategies supporting conservation harvesting goals in Canadian commercial fisheries. ($350,000).
- A Piglet Model to Describe and Quantify the Metabolism of Amino Acids by the Neonatal Gastrointestinal Tract($113,524).
- Music, Media and Place: The Traveling and Translation of ‘’Tradition’’ ($125,000)
- Marine Bioscience ($147,549).
- Infrastructure for the proposed Chair in Irish Studies, Memorial University of Newfoundland ($50,000).
- Petroleum Reservoir Engineering and Characterization ($125,000).
- Provide new equipment essential to remain in an internationally competitive research position, furnish woodchuck colony with diagnostic and operative equipment, and expand long-term capabilities ($125,000).
- Reservoir Geology Laboratory for data acquisition, data analysis and project documentation ($39,956).
- Canadian Research Chair in North Atlantic Archaeology: Laboratory, Field and Data Management Equipment ($125,000).
- Boreal and Cold Ocean Systems ($97,256).
- Structural and Material Testing for Offshore Applications ($400,000).
- Real Time Ocean Observatory at Bonne Bay Marine Research Center ($1,797,00).
- Center for Chemical Analysis and Applied Research (CCAAR) ($301,379).
- Memorial University Computer Network Upgrade ($822,124).
- Marine Aquaculture Research and Development Facility ($1,895,200).
- Development of a Canadian Earthquake Modeling Capability ($51,256).
- Facility for modeling, simulation and visualization for petroleum geoscience and engineering ($1,542,110).
- Digital Research Centre for Qualitative Fieldwork ($103,766).
- Fishery By-Products Research Centre: Infrastructure for the identification, recovery, and commercial development of marine biomolecules from fisheries and aquaculture wastes ($890,800).
- Memorial University Advanced Computation and Visualization Center ($679,801).
- Integrated environment for climate and oceanic-atmospheric fluid dynamics research ($94,489).
- Laboratory for Brillouin Spectroscopic Analysis and Characterization of Porous Semiconductor Systems ($113,339).

- Equipment for Marine Ecophysiology and Aquaculture Research ($79,356).
- Immunology of HIV Infection (137,000).
- Infrastructure to study the regulation of gene expression by nutrients ($73,825).
- Neural mechanisms regulating dopamine neurons involved in reward and addiction ($100,585).
- Initial Computing Infrastructures and Beowulf Cluster ($75,000).
- Infrastructure for the investigation of low-dimensional magnetic systems as a function of temperature, magnetic field and pressure ($42,917).
- Centre for Environmental Archaeology and Cultural Systems in Central Labrador ($64,039).
- A New Initiative in Fisheries and Marine Sciences at Memorial University of Newfoundland Application of New Acoustic Technologies to the Newfoundland Marine Ecosystem ($367,000).
- Detection of Genetic Variants for Obesity, Diabetes and Other Complex Diseases in the Genetically Homogeneous Population of Newfoundland ($166,931).
- Issues in human physiology and safety in Newfoundland's offshore industries ($185,323).
- Ocean Acoustics Infrastructure ($50,453).

Appendix C
Projects Funded in Newfoundland and Labrador Under the Atlantic Innovation Fund:[93]

- Canadian Centre for Fisheries Innovation - Atlantic-Wide Innovation Initiative for the Seafood Industry ($6,000,000).
- Centre for Cold Ocean Resources Engineering - Engineering Technologies for the Global Resource Markets ($6,000,000).
- College of the North Atlantic - Expand Regional GeoSpatial Innovation Capacity ($3,125,000).
- Memorial University of Newfoundland - Innovative Biotechnology: Enhancing Salmon Disease Resistance ($600,000).
- Memorial University of Newfoundland - Pan-Atlantic Petroleum Systems Consortium ($15,600,000).
- Memorial University of Newfoundland - Support for Atlantic Acquaculture - Broodstock development/fish health ($4,100,000).
- Memorial University of Newfoundland - The Electronic Rural Medicine Strategy ($1,300,000).
- Consilient Technologies Corp - The Consilient Server: A Wireless Network Operations Center ($1,700,000).
- Instrumar Limited - Develop technology for polymer fiber and other industries ($2,900,000).
- Newfound Genomics Inc. - Gene identification, ecogenetics of inflammatory bowel ($1,500,000).
- Northstar Technical Inc. - Aquacomm Project ($2,200,000).

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