State of the Nation 2008

Canada's Science, Technology and Innovation System

Science, Technology and Innovation Council

Canada

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Innovation, the Innovation System and Innovation Performance

Innovation is the process by which individuals, companies and organizations develop, master and use new products, designs, processes and business methods. These can be new to them, if not to their sector, their nation or to the world. The components of innovation include research and development, invention, capital investment and training and development.

This wide definition includes the invention of new products, processes, services and systems, as well as their application, adaptation and diffusion in the economy and society. Agents of diffusion include individuals, companies and colleges and universities. These users and producers of innovation are part of **the innovation system**, which also includes governments as facilitators and regulators. Adoption and diffusion are encouraged by public policy including financial assistance in the form of direct support and tax incentives, intellectual property policies as well as other marketplace frameworks such as competition and regulatory policies. Venture capital firms and other private sector investors that finance innovation are also part of the system.

Innovation performance is influenced by multiple sectors and public policies on education, science and technology, industry, and finance, developed by different levels of government. Immigration, international science and technology, trade and foreign investment policies also affect innovation outcomes.

Innovation in Canada

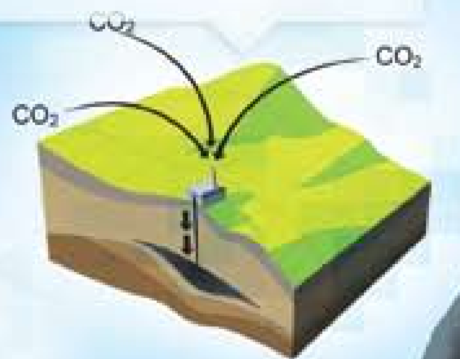
takes place in many sectors and stages of the value chain

Forestry

Canada's forest industry is working to increase the value of its resource by building flexibility into planning and manufacturing. Through one of their many R&D programs FPInnovations helps companies weigh the benefits of adopting advanced planning systems and flexible manufacturing techniques to improve efficiency and increase production of more profitable specialty grade products.

Energy — Oil and Gas Sector

Proving and piloting technologies on a real world scale is an important step before major investments are made in commercial facilities. In the oil and gas industry this step in the technology development value chain is characterized by a small number of high cost projects. Canada has such projects under way on unconventional natural gas development for coal bed methane and shale gas, and for the capture and storage of carbon emissions.



Transportation — Hydrogen and Fuel Cells

British Columbia's Hydrogen Highway vision is to accelerate the commercialization of hydrogen and fuel cell technologies. The Hydrogen Highway features five operational fuelling stations and numerous hydrogen and fuel cell products including cars, pickup trucks, shuttle buses, forklifts and mobile hydrogen stations. BC Transit's demonstration fleet of 20 hydrogen fuel cell buses will provide regular transit service in Whistler, a site of the 2010 Olympic Winter Games. Hydrogen fuel cell buses produce no smog-creating emissions and no greenhouse gas emissions, and they can be twice as efficient as internal combustion engines.

Financial Services

Service sector innovations can result in broad economic impacts and help individuals. New financial services may facilitate transactions and capital allocation, leading to widespread gains in productivity. The invention of mutual funds gave consumers an investment vehicle to diversify investment portfolios with a relatively small investment. Scotiabank has developed a new savings program that lets people automatically round up every purchase made using a Scotiabank debit card to the next multiple of $1 or $5. The roundup amount chosen is automatically transferred to a savings account helping customers achieve their savings goals.

Media

The Internet and electronic media have been catalysts for innovation in the newspaper industry. The availability of free online news has contributed to a decline in readership for printed newspapers, squeezing sales revenues and the emergence of free online bulletin boards has been cutting demand for classified ad space, another important source of revenue. To address these competitive pressures, many newspapers have established significant online presences reinventing themselves through innovative business models. Canadian newspapers are experimenting with combinations of free online content, subscriptions, writer's blogs, and discussion fora in which readers can voice their opinions on recent articles.

Entertainment

Montréal-based circus entertainment company Cirque du Soleil is now an international company with annual revenue exceeding US$700 million and more than 4000 employees including 1000 artists from over 40 countries. Cirque's International Headquarters (IHQ) is a world-class creative laboratory. Still mainly dedicated to creating live shows and presenting them in venues ranging from big tops to arenas, Cirque du Soleil will have 19 different shows performing around the world in 2009. Cirque is committed to integrating excellence in the performing arts with state-of-the-art international technology. Geodezik, a Montréal-based multimedia design and production company, used the award-winning Pandora's Box Media and Showcontrol system to provide video system and content design for the Cirque's first permanent show in Asia, ZAIA. ZAIA tells the story of a young girl's journey through interstellar space, blending light and 3-D visual elements into each scene.

Design and Marketing

Design is a new and underestimated aspect of innovation. The success or failure of new products, based on technological innovation, may depend on their design. Design can address existing needs for example, ergonomic keyboards, or be for purely aesthetic purposes. Graphic design and marketing services derive much of their value from the novelty of the service being provided, and so are innovation-driven industries.

Role of the Report

The Science, Technology and Innovation Council (STIC) was created in October 2007 to provide integrated advice to the Government of Canada through the Minister of Industry. The intention to create a single integrated Council was announced by Prime Minister Stephen Harper in the May 2007 *Mobilizing Science and Technology to Canada's Advantage*, a new framework to guide Canada's science and technology policy. The STIC's value comes from drawing on members' different areas of expertise and perspectives to provide an integrated consensus view on the challenges and opportunities Canada faces. The STIC intends to report fully and candidly. This State of the Nation report will take stock of Canada's performance in areas that affect our ability to innovate. It will also present the stories of a sample of Canadian innovation leaders and models. Canadians have achieved and will continue to achieve excellence on an international level if that is our benchmark. This year we set out a baseline from which we can monitor dynamic progress. We point to areas where we hold our own, and where we excel, as well as where we are underperforming and where attention is needed.

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Context and Executive Summary

This report provides an overview of the health of Canada's science, technology and innovation system. The report charts Canada's progress over time and compares Canadian performance to the performance of science, technology, and innovation leaders around the world. Finally, it identifies areas that deserve our attention if we aspire to position Canada in the leading group of innovating countries.

Innovation matters. In a globalized world, creating and retaining jobs for Canadians and improving our living standards will increasingly be linked to our ability to innovate. Our living standards and quality of life will rise with more energy efficient cars and airplanes, new treatments for diseases, better access to the Internet, and communication devices that connect us as communities and to the global economy. Our ability to tackle the issues important to Canadians — whether they be cleaner and more energy efficient use of our resources, or the ability to provide services across vast distances — will depend on a strong science base and a capacity to innovate.

While Canada's innovation potential is unbounded, there are challenges to face. The current global financial crisis has hurt our economic performance, particularly in the automotive, forest products, information technology and biotechnology sectors. It is reducing the revenues available to the private sector, universities, colleges and government.

At the same time we face longer-term challenges. Technological frontiers move outward at an accelerating pace, making it difficult to stay at the leading edge. Global and national challenges, such as climate change, energy consumption and production, and the costs and implications of an aging population, demand action. New, lower cost, entrants to the global economy increase competitive pressures on our companies.

The current economic environment has reduced the margin for error and increased the risk and consequences of poor decisions. In times of economic hardship, research and development (R&D) budgets can be squeezed in companies, universities, colleges and governments. Ensuring that our decisions and investments result in long-term, sustainable economic growth, however, remains urgent and vital to our future.

Canada has made progress in the last decade in supporting an innovation system. We now know that if we want to create jobs and opportunity in a competitive world, science, technology and innovation must be on a national agenda that focuses support on those who drive our innovation success. Drivers of our innovation success include:

- a private sector that has science, technology, and innovation strategies at its core;
- institutions of education and research that develop, recruit, and retain strong talent pools; and
- researchers who keep us at the forefront of knowledge and workers who see and act on opportunities to work smarter and more creatively.

We have learned that innovation performance comes from how well these performers do individually and how well they collaborate with each other. Stimulating innovation requires sustained collaboration and a systemic response by different individuals and institutions in the innovation system working together. Municipal, provincial and federal government funding, and policies act as incentives to innovative activity. Policies can also promote and ease international collaboration, strengthening access to the global pool of knowledge and expertise. Companies, institutions and governments must be strategic and nimble with their science and technology (S&T) investments and decision-making to capitalize on emerging technological shifts and new economic and societal opportunities.

Achieving excellence with a defined level of resources requires making choices. On the advice of the STIC, the Minister of Industry recently announced sub-priorities that will focus resources and support discovery and applied research and innovation that build on Canada's competitive advantages. This will lead to accelerated development of areas of importance to Canada while recognizing that a substantial proportion of funding is dedicated to excellent basic research.

Assessment and Way Forward

By comparing Canada's performance against other countries, there is much that we can learn about the dynamism of our economy, and our ability to maximize the economic and social benefits of new research, products, services, processes and business models. We have choices to make and strengths on which we can build. There are also areas where our performance is not among the world's best. This is natural. No country leads in everything. To get to the very top, we need to know where we are now, understand how we got here, agree and act on where we choose to excel, and then track our performance relentlessly.

Canada is having difficulty keeping pace with the best innovators. Our benchmarking with others and against our own performance over time shows a pattern of modest improvement, but the effort has been insufficient to bring Canada to the G-7 average, let alone position Canada as an international leader. Canada remains in the middle of the Organisation for Economic Co-operation and Development (OECD) pack of 30 countries and sixth in the G-7 in business R&D as a proportion of Gross Domestic Product (GDP). Low overall business R&D and commercialization in Canada has been a constant feature for 40 years.

There are some distinct Canadian characteristics worth observing. Canada has one of the most advantageous innovation tax incentives in the world providing between $3 and $4 billion in the form of the Scientific Research and Experimental Development (SR&ED) tax credit. Eighty percent of venture capital (VC) is used in the information, communications and technology and pharmaceutical industries. Public policy and business realities have made universities more important centres of R&D than in other countries.

> [...] innovation is more than R&D.

At the same time, we need to emphasize that innovation is more than R&D. Many companies are bringing value to the market by using knowledge that does not necessarily come from R&D. We have significant limitations in measuring this type of innovation — that is knowledge gained through learning by doing and using and through collaboration outside the firm.

There will be profound changes in the North American and global economies in the coming years, reflecting changes to the industrial structure and the emergence of new economic realities. The best way for Canada to adapt to these changes, and even excel under these trying circumstances, is to ensure that our economy is flexible, efficient and dynamic. Shaking off complacency to achieve a more innovative Canadian economy will not only need a dedicated commitment of resources: it will require providing the right stimulus and incentives for innovation; fostering a business culture that sees innovation as a key driver of value; and enhancing the capacity of all elements of our innovation system to work together to create value for all Canadians.

The STIC examined sets of indicators that measure the performance of individuals, institutions and companies. Current indicators are not sufficient to the task. For example, we chose not to include a more detailed discussion of business R&D by sector, as conclusions would have been based on 2002 data, which were the most recent data available.

We know that innovation activities that result in new products and processes are reasonably well captured in data presented, but innovation that results in new business models, business practices or market development is not. This is a result of relatively infrequent surveys of innovation in services, manufacturing and in resource-based industries, and often, the difficulty in comparing international results by sector.

We are also limited in understanding the dynamics of collaboration. Our data allow us to count the number of collaborations by companies or public research institutions, but we know very little about the kinds of collaboration being done. We also do not know which collaborations have been successful and which have not, whether collaborations differ by industry, or the extent to which these collaborations involve only domestic companies or are global in nature. Many of the same challenges exist for international patent data, which is why data on patents have not been included in this report.

Much of the information that we need to analyze the profound changes in our economy will have to come through surveys of innovation plans, activities, linkages and outcomes. Surveys will need to be carried out with sufficient frequency to illuminate change. Businesses and governments need to think now about how official statistics are structured and compiled. They need information to help them assess the economic and social impacts of innovation. At the same time information must be collected in ways that minimize costs to respondents, particularly small and medium-sized businesses.

If Canadian research and entrepreneurship are conducted at international levels of excellence, they will continue to be a source of national pride and prosperity.

Canada has a proud history of scientists who pushed back the frontiers of knowledge to benefit humankind. Canadians have made groundbreaking discoveries and turned scientific discoveries into the products and services that make our lives better. Just as we prepare our athletes to be the best, we must enable our scientists and entrepreneurs to learn by working and competing with the best. If Canadian research and entrepreneurship are conducted at international levels of excellence, they will continue to be a source of national pride and prosperity.

To move forward we recommend devoting attention to the following areas:

Talent — developing a highly qualified workforce attuned to innovation opportunities

- Young Canadians are excelling in science, mathematics and reading in comparison to their peers in the OECD, ranking in the top five in each of these categories. We must keep up with others who are improving their rankings.
- In comparison to those in other OECD countries, few Canadian students are completing Master's and Doctoral programs in areas that drive discovery and innovation. Companies, governments, and universities can encourage more Canadians to complete advanced degrees by educating students on the range of S&T careers and providing students with career opportunities in S&T development, application, management and financing.
- Canadians in the workplace who apply and adapt new technologies can drive innovation to new levels. Canada has not made progress in a decade in increasing the proportion of Canadians with basic literacy and numeracy skills. Governments and employers must champion adult literacy and technology training to address this skills deficit.

Knowledge development and transfer

- In Canada, governments at different levels and the private sector have chosen to build research capacity at institutions of higher learning. Focusing resources of all sectors on research priorities, conducting research at international levels of excellence and better using research facilities at universities and colleges to train students in state-of-the-art facilities can help improve innovation performance and benefit companies.
- Turning R&D excellence into jobs and a better quality of life depends on building strong connections among customers and suppliers, scientists and managers and managers and teachers. We need to advance the transfer of knowledge between science and business.

Business Innovation

- Canadian companies do not invest as much as their competitors around the world in R&D. We have made little progress in understanding why these competitors are more likely to see investments in the lab and on the shop floor as contributing to their business goals. This understanding is fundamental to evaluating the efficacy of policy instruments to stimulate innovation.
- How Canadian technology companies finance their ventures and the availability of different sources of risk capital at different stages of business development can have a significant impact on commercialization success. Business associations and the venture capital industry can assist in the understanding of this area.

Tracking Progress

- More resources and greater effort must be devoted within the innovation system to capturing data, which better explain how individuals, companies and other institutions innovate. This can be done through business R&D and innovation surveys, sector specific technology surveys and user surveys on information technologies and their applications. Without the tools to understand how innovation happens, we will be unable to formulate appropriate strategies for improving innovation performance.

Conclusion

All participants in the innovation system have a role to play in strengthening Canada's innovation capabilities. In the STIC's view, Canada has strong foundations on which to build. Many Canadians are leading the way with the support of all levels of government. If we adapt international best practices for Canada, focus our domestic efforts, maintain a watch on key indicators for success, relentlessly test the efficacy of our innovation support mechanisms, and act quickly to address areas of weakness Canada will be able to compete with the best.

1. Introduction

Strength and leadership in science, technology and innovation (STI) is the price of entry to full participation in the knowledge-based global economy of the 21st century. To thrive in the new global economy, a country must innovate. Deep and comprehensive capacities to discover, create, source, adopt and market new goods and services underpin our country's future economic growth and each citizen's quality of life. Improvements in our health, personal security, and the quality of our environment all go hand-in-hand with our ability to innovate.

What drives innovation in Canada? Curiosity and the thirst for knowledge, the desire to succeed in the marketplace, better services for Canadians, better stewardship of our environment and resources, and realizing our full potential, motivate individuals, institutions of learning, businesses and government.

The potential for the future is enormous. Canada has significant S&T strength and is building core S&T advantages — our people, our communities, our enterprises and our knowledge. We have fostered businesses that are able to compete effectively in the global arena and our population is one of the most educated in the world. Our researchers make significant contributions to the global pool of knowledge. Our marketplace frameworks help make Canada a prosperous nation and an attractive destination for investment. Two official languages and vibrant, diverse, tolerant, communities where culture and the arts thrive, enrich the lives of Canadians and draw others to our country. As the Competition Policy Review Panel observed: "Canada also provides political stability through strong institutions and a commitment to the rule of law, an increasingly important competitive asset for economic and resource development."[1]

Recent assessments of Canada's innovation performance, however, tell us that all is not well. The Council of Canadian Academies in their 2006 report, *The State of Science & Technology in Canada*, concluded that Canada has built significant strength in many fields of research over the last decade and is gaining ground in many new areas such as bio-based and health sciences, various applications of nanotechnology and natural resources. However, Canada did less well in "converting strength in basic science into sustained commercial success."[2] In its 2007 *report card* the Conference Board of Canada still places Canada in the gifted class among nations, but tells a story of a country moving to the back of the class because of underperformance in almost all subjects. Canada received a *D* grade and ranked 13th out of 17 countries in the area of innovation, making us a below-average performer with only *pockets of achievement*. The Competition Policy Review Panel linked much of Canada's poor productivity performance to the comparatively poor performance of Canadian companies in the creation, diffusion and transformation of knowledge and the use of knowledge through commercialization.[3]

Maintaining our investments in science, technology and innovation will help us ensure that we bounce back quickly from the current global economic downturn. Our investments in science, technology and innovation can help us to build our current strengths, help us to leapfrog competitors who are not in as good financial shape as we are, and provide us with opportunities to shore up the areas where we are not among the world leaders. But failing to act, or making the wrong decisions, will turn the short-term problems we face in the current global financial crisis into a long-term, possibly permanent decline in our living standards. Now is the time to *up our game*.

[1] Competition Policy Review Panel, *Compete to Win* (2008), p. 24.

[2] The Committee on the State of Science and Technology in Canada, Council of Canadian Academies, *The State of Science & Technology in Canada*, 2006, p. 25.

[3] Competition Policy Review Panel, *Compete to Win* (2008), p. 18.

2. Overall Assessment of Indicators

2.1 Business Innovation Indicators Assessment

More companies need to recognize the important role that technology and innovation can play in their business strategy and performance. An entrepreneurial culture is important in fostering innovation at all levels of society, from the scientists and managers who bring science to the market in the form of new products, to the workers on factory shop floors who devise more efficient ways of running their production lines and find new applications for their equipment. Those Canadian firms that do more research and development (R&D) have greater sales of new products and are also more productive.

In general, Canadian firms have increased their R&D investments, but in relative terms, we are falling behind our major competitors, and the gap is growing. Previous studies have shown only a few industrial sectors account for the low aggregate business R&D intensity in Canada relative to the United States (U.S.). In these studies, almost the total gap is accounted for by low business R&D intensity in the services sector and the motor vehicle industry. However, sectoral differences in business R&D intensity and the reasons for differences between comparable Canadian and U.S. industry sectors are not particularly well understood.

Recent analysis by Statistics Canada has shown that when industry structure is taken into account for machinery and equipment investment, most Canadian industrial sectors are less capital intensive than those in the U.S. In the case of machinery and equipment investment that is not related to information and communications technologies (ICT), the gap with the U.S. is about 12 percent. The deficit is more pronounced for ICT investments — about 33 percent.

Section 2 summarizes the assessment of sets of indicators presented in the *Digest of Key Indicators* found in Section 4.

Amongst the countries compared, Canada ranks 7th for the percentage of Gross Domestic Product (GDP) invested in venture capital. This is expected to worsen because of the current global credit crunch.

Not only does Canada spend less on machinery and equipment, but we do not, as a rule, develop the equipment in Canada. More than 55 percent of manufacturing plants that introduce advanced technologies to the market in Canada are most likely to be technology purchasers. There is considerable *user-driven* innovation taking place with 42 percent of firms either modifying the technology they purchased or developing technology themselves in-house.

The Organisation for Economic Co-operation and Development (OECD) has begun to compare total direct versus indirect support by government of business R&D for the 13 OECD countries for which data are available. Their findings show that when direct support is added to the value of indirect support of business R&D, Canada has the richest government support of business R&D, as a percentage of GDP, just edging out the U.S.

Canada's government support of business R&D in 2005 was equal to 0.23 percent of GDP, just ahead of the U.S., where government support of business R&D was equal to 0.22 percent of GDP. While the total (i.e. indirect plus direct) government support of business R&D is similar, 90 percent of Canadian support was for indirect measures (the business R&D tax credit), while 80 percent of government support in the U.S. was for direct government funding of Business Enterprise Research and Development (BERD), and only 20 percent of U.S. government support of business R&D went for indirect measures. Direct government funding of business R&D, coupled with effective procurement policies, have proven successful for economic development in knowledge-based societies like Finland, the U.S. and Korea.

Finally, *open innovation* is growing as firms increasingly collaborate with their customers, suppliers and research institutions to source new innovative ideas, products and services. Canada's poor performance on a range of indicators, including examining the percentage of firms collaborating with each other or with other research organizations in innovative activities, is troubling.

2.2 Knowledge Development and Transfer Indicators Assessment

Canada's universities are a key component of the national innovation system. Canadian university researchers are prolific publishers, and their research tends to be of a high quality, particularly in a number of fields. Whether measured as a share of total national R&D or as a share of GDP, the university sector's contribution to national R&D in Canada is larger than that of most OECD and G-7 countries. Funding for university R&D in Canada was fairly stable from 1990–97, but grew quite rapidly every year following 1998. While federal direct R&D funding and provincial government transfers to universities are the principal sources for university R&D funding, Canadian businesses fund university research to a higher degree than in other countries. Licensing revenues to Canadian university R&D are lower than in the U.S., but Canadian universities tend to produce research-based spinoff companies at a higher rate than other countries, including the U.S.

A number of studies suggest distinct aspects of university–business linkages. R&D cross funding between the Canadian business sector and universities is high by international standards, both as a share of total Canadian research and as a share of GDP. However, the proportion of Canadian businesses collaborating with universities on R&D is low by international standards. The state of university–business R&D collaboration in Canada was not ranked highly by the World Economic Forum Competitiveness Survey. Since there is strong evidence that businesses can benefit from research and innovation collaboration with universities, it is important to understand why these various sources give apparently conflicting conclusions on the state of inter-sectoral collaboration in Canada.

While Canadian universities tend to use spinoffs as a vehicle for commercialization of research more than in other countries, the number of spinoffs from Canadian universities has dropped in recent years. The rate of licensing of Canadian university research remains far below the rate of the U.S.

Canadian universities are not well represented in international university rankings (including private universities), suggesting poor international recognition or low institutional quality. An examination of institutional quality would need to explore the links between outcomes and resourcing, that is, the relative levels of funding of research universities in Canada and abroad.

The government plays a crucial role in funding knowledge generation and diffusion. Funding for university R&D comes primarily from government sources (either provincial or federal) and numerous government programs exist to foster R&D linkages between universities and business. Federal government agencies also carry out important scientific activities. These activities include research related to regulatory and information mandates of governments, and R&D on issues of strategic importance to the nation and to Canada's economy. Funding for Canadian government R&D has been fairly stable since the late 1980s, even in inflation-adjusted dollar terms. However, as a share of GDP, funding for government R&D has not kept pace with growth in the economy. As a share of GDP, Canadian funding for government R&D is well below the G-7 average, and the gap between Canada and the G-7 has grown in recent years.

2.3 Talent Indicators Assessment

In a world where talent is everything, Canada must devote attention to developing the full potential of its citizens. At present, we risk being surpassed by others who are improving more rapidly.

Our 15 year-old students have one of the highest aptitudes for science, math and reading, but others are improving and so must we.

Two in five working age Canadians lack the skills to cope in a knowledge-based economy. As virtually no progress has been made in this area in a decade, this should be a major preoccupation for governments at all levels.

Our track record of investing in training in the workplace has also been poor for over the past decade. Those in the workplace must regularly update their skills in order to adapt to new innovations. In turn, employees can also be a source of innovative products, processes and services. Canada ranks first in the OECD in the proportion of its working age population attaining tertiary level education. We place 21st in the OECD, however, in the number of science and engineering degrees as a percentage of new degrees.

Although university enrolment in Canada is high in business-related fields compared to other fields, it is low compared to other countries. Canadian companies may therefore employ fewer individuals with advanced business skills than our international competitors employ.

Canada's capacity to innovate also depends on our ability to attract talented researchers and scientists. In the face of global competition, Canada must remain diligent in working to recognize foreign credentials so that skilled newcomers can contribute to Canadian society. Recent changes in the post-graduate work permit program and a fast-track immigration route for skilled foreign workers should assist attraction and retention efforts.

Canadians receive a disproportionate share of the world's major awards, doing especially well in the fields of the environment, medicine and technology. However, we have fallen behind in recent decades in attaining the very best awards: the Nobel Prize, the Wolf Prize, Fields Medals and others. Support mechanisms across the innovation system must drive research excellence and recognition of our top talent at international standards.

3. Foundations for Innovation — Elements of the Innovation System

The Competition Policy Review Panel's June 2008 report entitled *Compete to Win* defined productivity as the efficiency with which resources available to an economy, such as labour, capital, and business expertise are being used to produce goods and services.[4] Productivity reflects our ability to make the best use of our people and other resources to increase our standard and quality of life. There is a strong empirical link between innovation and a nation's productivity.[5]

This section describes the conditions that support a well-functioning innovation system, comments on local and international factors influencing innovation, and discusses research areas of focus to build innovation strengths. It then provides an overview of the resources for R&D and Canada's principal R&D performing sectors.

3.1 Supporting Good Performance

A healthy innovation system requires the right conditions:

Supportive Marketplace Frameworks — Policies and practices that create strong, open, competitive domestic markets where ideas can be taken from conception to application.

Engaged Citizens — Individuals and businesses that demand better quality products and services, for themselves and their communities driving manufacturers and service providers to become more innovative.[6]

Highly Skilled People — People who have leading edge research skills and people who know how to put new technology to work.

Infrastructure — A modern physical and regulatory infrastructure to ensure the free flow of goods, services and ideas.[7]

Accurate Measures of Performance — Statistics that better reflect plans, activities, linkages and outcomes of innovation so that we can determine the full impact of innovation on the Canadian economy, and measure how well we are doing against global competition.

Underpinning these conditions is the vital need for collaboration. Greater cooperation and collaboration between the private sector, universities and colleges, all levels of government, and others[8] at the regional and national levels strengthen a nation's ability to compete at the international level. Collaboration is also vital to foster multidisciplinary research, which is integral to the knowledge-based economy.

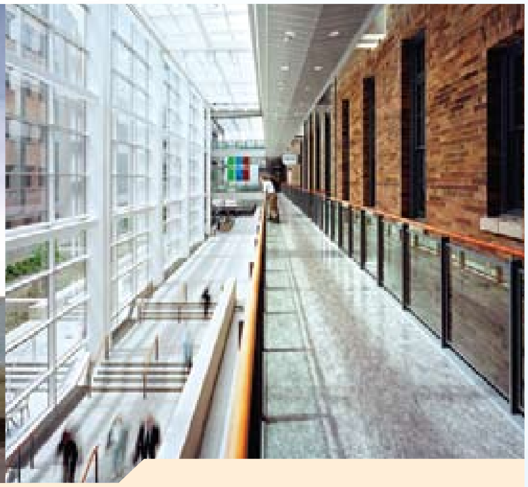
4 Competition Policy Review Panel, *Compete to Win* (2008), p. 4.

5 S. Rao, A. Ahmad, W. Horsman, and P. Kaptein-Russell, "The Importance of Innovation for Productivity." *International Productivity Monitor*, No. 2 (Spring 2001), pp. 11–18.

6 This ranges from a citizen demanding better health care to an individual consumer who buys a product from a store to a large corporation that purchases input parts from suppliers.

7 While Canada was among countries with the highest levels of infrastructure in the OECD as of 2000, its position has been slipping in recent years. Centre for the Study of Living Standards, *Assessing Canada's Ability to Compete for Foreign Direct Investment*, paper commissioned by the Competition Policy Review Panel, 2008.

8 Including health charities, not-for-profit organizations, etc.



MaRS Innovation

To succeed in global innovation, Canada has to create more homegrown commercialization success stories.

Enter MaRS Discovery District: a Toronto-based public–private partnership.

As a non-profit innovation centre, MaRS connects science, technology and social entrepreneurs with business skills, networks and capital to stimulate innovation and accelerate the creation and growth of successful Canadian enterprises.

This happens physically at the 700 000 sq. ft. MaRS Centre, which is home to a mix of research labs, companies of all sizes — including multinationals, Canada's largest bank and venture capital firms — as well as more broadly through hands-on market research and other advisory services for entrepreneurs, inventive programming and an expanding electronic community.

Anchored by major teaching hospitals, the University of Toronto and more than two dozen affiliated research institutes, the MaRS Centre attracts interest and delegations from across Canada and around the world.

Recent work in the U.S. by Fred Block and Matthew Keller at the Information Technology and Innovation Foundation, which looked at the extent of collaboration between organizations for winners of *R&D Magazine's* "R&D 100 Awards" from 1971 to 2006, found that:

> Whereas the lion's share of the R&D 100 Award-winning U.S. innovations in the 1970s came from corporations acting on their own, most of the R&D 100 Award-winning U.S. innovations in the last two decades have come from partnerships involving business and government, including federal labs and federally funded university research. Indeed, in the 1970s, approximately 80 percent of the award-winning U.S. innovations were from large firms acting on their own. Today, approximately two-thirds of the award-winning U.S. innovations involve some kind of interorganizational collaboration — a situation that reflects the more collaborative nature of the innovation process and the greater role in private sector innovation by government agencies, federal laboratories, and research universities.[9]

Intense global competition and the rising cost of R&D are changing how companies innovate, and increasing the need to collaborate across firms, universities and governments. More information about the importance of firm collaboration and Canada's performance on this measure is discussed in Section 4.1 of this report.

In order for our innovation system to realize its full potential, all elements must work together to create and nurture the overall conditions under which innovation can thrive in all sectors of the system. Governments have a crucial role to play in encouraging coordination and promotion of S&T. The STIC views the provision of its advice as an opportunity to spur collaboration between the different elements of the science, technology and innovation system.

[9] Fred Block and Matthew Keller, *Where do innovations come from? Transformations in the U.S. national innovation system, 1970–2006* (Information Technology and Innovation Foundation, July 2008); pp. 2–3 accessed at: http://www.itif.org/files/Where_do_innovations_come_from.pdf.

3.2 The Importance of Healthy Communities

As recent studies have shown, talented people (those who play the lead role in knowledge-intensive production and innovation; and provide the ideas, know-how, creativity and imagination so crucial to economic success) are not spread equally across nations, but tend to concentrate within particular city regions. The most successful city regions are the ones that have a social environment that is open to creativity and diversity of all sorts. Communities of creative people active in arts and culture that are open to diverse ethnic, racial and lifestyle groups, provide distinct advantages to regions generating innovation, growing and attracting high-technology industries and spurring economic growth.[10]

Canada's respect for diversity and our engaged citizenry attract talented and creative people from all nations. Canada is a top destination for highly skilled immigrants. In 2004, Canadians donated an estimated $8.9 billion to charity, an average of $400 each and contributed a total of two billion hours to voluntary efforts, the equivalent to one million full-time jobs.[11] Residents have access to high quality and comprehensive public health and education systems. According to the United Nations Human Development Index 2007, which combines social and economic well-being indicators, Canada ranks fourth among 177 nations. A *liveability* study, published by the Economist Intelligence Unit (EIU) in the summer of 2008, awarded Vancouver first place, while Toronto placed fifth and Calgary placed seventh out of 123 cities.[12] Finally, according to Mercer's 2008 *Quality of Life Survey*,[13] which compares 215 cities based on 39 criteria, Vancouver ranks 5th, Toronto 15th, Ottawa 19th, Montréal 22nd and Calgary 25th. Canadian cities rank high because they benefit from good infrastructure, plenty of recreational activities, low crime rates and relatively low population density.

Tracking Water Contaminants to Their Source Protects Health

Safe drinking water is essential to the health of Canada's population. The outbreaks of disease and death in recent years due to contaminated drinking water have greatly heightened Canadians' concerns over water-borne disease. Dr. Asit Mazumder, a Natural Sciences and Engineering Research Council of Canada Industry Research Chair in Water at the University of Victoria, led a four-year Canadian Institute of Health Research funded collaborative study to track the sources of coliform bacteria contamination in several watersheds in Okanagan and Salt Spring Island in British Columbia. To ensure knowledge transfer, Dr. Mazumder's research team partnered directly with federal and provincial government departments, industries (forestry and livestock) and municipalities.

As a result of the study, Dr. Mazumder's lab (www.uvic.ca/water) developed a unique risk assessment tool for measuring potential damage to water supplies from fecal (human, livestock and wildlife) contamination of source water. The new approach combines the use of molecular (DNA) markers with biochemical and geochemical markers of septic and sewage origins. The tool is currently in use, through cooperation with Dr. Mazumder's lab, in several British Columbia municipalities, such as Victoria, Kamloops, Vernon, Prince Rupert, and Kelowna. His lab is currently working with federal and community partners to characterize and model safety of groundwater in First Nations communities across Canada. In the summer of 2009, Dr. Mazumder will present the risk assessment tool to researchers and managers at the International Symposium on Environmental Science and Technology in China.

10 Meric S. Gertler, Richard Florida, Gary Gates, and Tara Vinodrai, *Competing on Creativity: Placing Ontario's Cities in North American Context.* A report prepared for the Ontario Ministry of Enterprise, Opportunity and Innovation and the Institute for Competitiveness and Prosperity, November 2002, p. ii.

11 Statistics Canada, *Caring Canadians, Involved Canadians: Highlights from the 2004 Canada Survey of Giving, Volunteering and Participating,* Catalogue no. 71-542-XIE, June 2006, pp. 9–10.

12 In the EIU's list, Ottawa and Edmonton also ranked within the top 25.

13 Mercer's list is especially important, since it is often used by companies to determine where they will open plants or offices and how much they pay their employees.

3.3 International Realities and Opportunities

Innovation is taking place all over the world, and Canada operates in a global economy. Large firms are multinational, often with significant operations in many parts of the world. Even small firms are tied to the international environment through their supply chain and through the goods and services that they export. The labour market for highly qualified personnel is transnational and highly mobile. The global economy has many new entrants from non-traditional sources that strive to carve out an internationally competitive niche. This has the effect of raising the overall level of competition.

In the last 10 years, we have seen changes in how and where S&T takes place globally, which in turn have resulted in changes in production and the trade of both goods and services. Users and consumers are driving demand for innovations. At the same time, access to information and communications tools is driving a network economy and new business development models. Faced with shorter and increasingly complex production cycles, and with greater access to highly skilled and less expensive employees around the world, companies are moving away from traditional in-house R&D. Company alliances have global reach. Higher education institutions, various levels of government, and not-for-profit research organizations are seeking the best talent, ideas and knowledge wherever they exist in order to leverage in-house assets and create economic and social value. Major research initiatives in science often involve collaboration among nations, researchers and companies. Some collaboration takes place within Canada — for example in major initiatives such as SNOLAB and TRIUMF. Canada also participates in international initiatives located around the world, including, for example, the European Organization for Nuclear Research — CERN and astronomy telescopes such as the Canada–France–Hawaii Telescope and Gemini North and South.

China and India are emerging as key competitors and collaborators. According to the OECD, China is now the third largest investor in R&D globally. India ranked first in a recent Economist Intelligence Unit survey on best overall overseas location for R&D. The U.S. and China were second and third.[14]

Interaction between scientists in touch with the most profound developments in their fields advances knowledge. The cross-fertilization of skills and ideas at the researcher level supports a range of research from basic curiosity-driven research to research that is closer to commercialization.

Canadian Light Source and International Collaboration

The Canadian Light Source (CLS) at the University of Saskatchewan in Saskatoon is Canada's national centre for synchrotron research — the use of brilliant light to view the microstructure of materials. This extremely bright light is produced by using powerful magnets and radio frequency waves to accelerate electrons to nearly the speed of light. Information obtained through the CLS enables scientists to gain powerful insights into substances as varied as soils, mine wastes, ores and minerals, biological tissues, functional foods and nutrient supplements, leading to a wide range of innovative products and processes that can improve life on the planet.

University of Saskatchewan Canada Research Chairs Graham George and Ingrid Pickering have used the CLS synchrotron to conduct research with profound applications. The contamination of well water by natural arsenic has resulted in the mass poisoning of nearly 100 million people in Bangladesh and the surrounding Ganges River Delta. Soil selenium levels in the area are very low, and the scarce selenium ingested is leached from the body in the arsenic selenium molecule. Selenium is essential to human health. Symptoms of selenium deficiency can closely resemble those of arsenic poisoning. George, Pickering and co-workers hypothesized that rather than arsenic poisoning, these Bangladeshi are actually suffering from selenium deficiency. The University of Saskatchewan team is now part of an international collaboration conducting a clinical trial of selenium supplementation in Bangladesh.

[14] The Economist Intelligence Unit, *Scattering the seeds of invention: The globalisation of research and development.* 2004, p. 9.

Canadian business, academic and government organizations need to have enough internal capacity to be able to absorb and adapt foreign knowledge. While it is true that the benefits of international R&D spill over into Canada, innovation leadership does not come from being a nation of free riders. To ensure that R&D is conducted in areas of importance to Canada and to better capture the benefits of international efforts, Canada needs a domestic S&T capacity that is both a source of world-class excellence and is capable of accessing excellence wherever it may be.

3.4 Building Innovation Strengths — Research and Development Sub-Priorities

For an economy and population the size of Canada, it is not possible to participate in all international initiatives or to conduct all our research domestically.[15] We must be strategic as to where we focus our resources and how we capitalize on global excellence wherever it may reside. For this reason, the Government of Canada selected four priority areas for research:

- Environmental science and technologies
- Natural resources and energy
- Health and related life sciences and technologies
- Information and communications technologies

In September 2008, the Minister of Industry, based on advice from the STIC, announced 13 research sub-priority themes of significance to the nation (Figure 1). The sub-priorities[16] were identified to focus attention on strategic areas of R&D, and enhance Canada's competitiveness. The sub-priorities cover both basic and applied research and innovation, and will serve as a springboard to leadership by Canada in areas of significance to the nation.

Figure 1: Research and Development Priority Areas and Sub-Priority Areas

Environment	Water: • health • energy • security
	Cleaner methods of extracting, processing and utilizing hydrocarbon fuels, including reduced consumption of these fuels
Natural Resources and Energy	Energy production in the oil sands
	Arctic: • resource production • climate change adaptation • monitoring
	Biofuels, fuel cells and nuclear energy
Health and Life Sciences	Regenerative medicine
	Neuroscience
	Health in an aging population
	Biomedical engineering and medical technologies
Information and Communications Technologies (ICTs)	New media, animation and games
	Wireless networks and services
	Broadband networks
	Telecom equipment

15 *Compete to Win* notes that Canadian firms have to look beyond their borders to achieve the scale necessary to compete with global rivals.

16 Sub-priorities are not ranked within or across categories.

Water — Hydrology, Ecology and Health in Canada's North

The Arctic Freshwater Systems Hydrology and Ecology Project is one component of a broader Canadian science and research program. The project represents one of Canada's contributions to a multidisciplinary, international scientific and social research effort, the International Polar Year (2007–08). Canada's work built on existing programs, networks and facilities to focus on two important challenges for Canada's northern regions: climate change impacts and adaptation, and the health and well-being of northern communities.

The project mobilizes a multidisciplinary field and laboratory research network. Its objectives are: to assess ecological biodiversity and the integrity of Arctic freshwater ecosystems and food webs; to improve understanding and prediction of freshwater flow and nutrient transport to the Arctic Ocean; and to develop a legacy database of water, biodiversity and related environmental information for Arctic freshwater ecosystems.

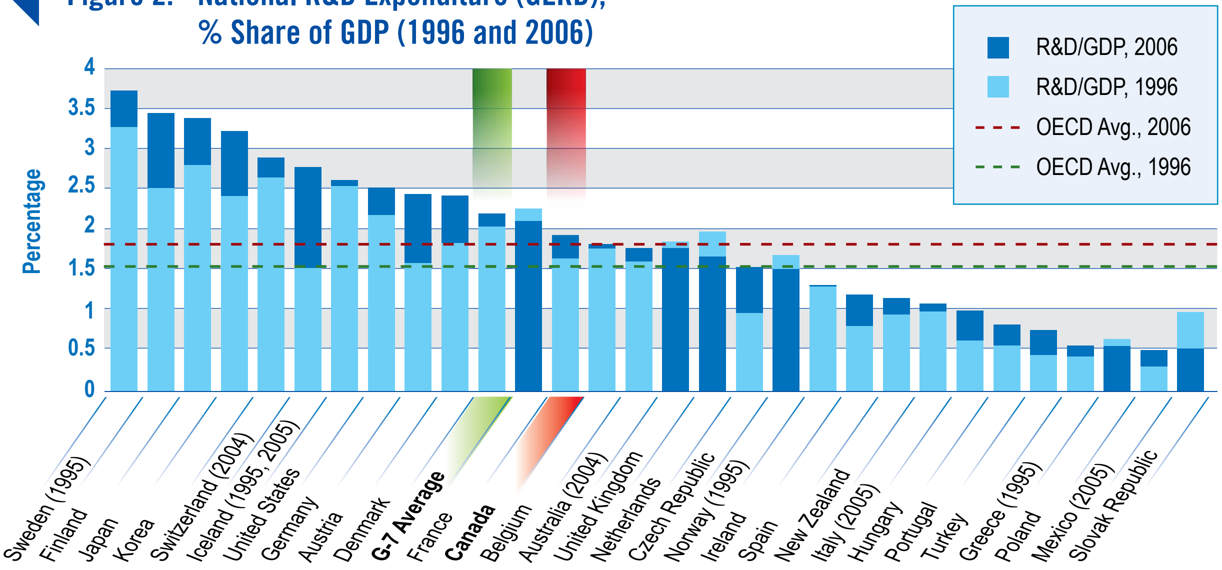
The project's training and outreach program engages young scientists, Northerners and Northern communities in on-the-ground training in science and research activities. The project also provides for the acquisition and incorporation of traditional knowledge. It will lead to a new generation of polar scientists, particularly Northerners and Aboriginal peoples, carrying on strong northern research programs in the decades to follow. With new knowledge, these scientists will be able to monitor the quality and sustainability of traditional foods as well as the status of the Arctic environment.

Jennifer Nafziger, a student at the University of Alberta, and Tom Carter of Environment Canada measuring the velocity of ice floes during spring breakup of the Mackenzie River at Tsiigehtchic, Northwest Territories. (Photo: Spyros Beltaos)

3.5 Resources for Research and Development

A commonly used measure of a country's innovation performance is the share of national R&D expenditures (gross domestic expenditures on R&D [GERD]) relative to the size of that country's GDP. While this is a somewhat crude measure, it is useful as a benchmark of a country's overall international standing. This measure has been used as a target by various national science, technology and innovation strategies around the world.

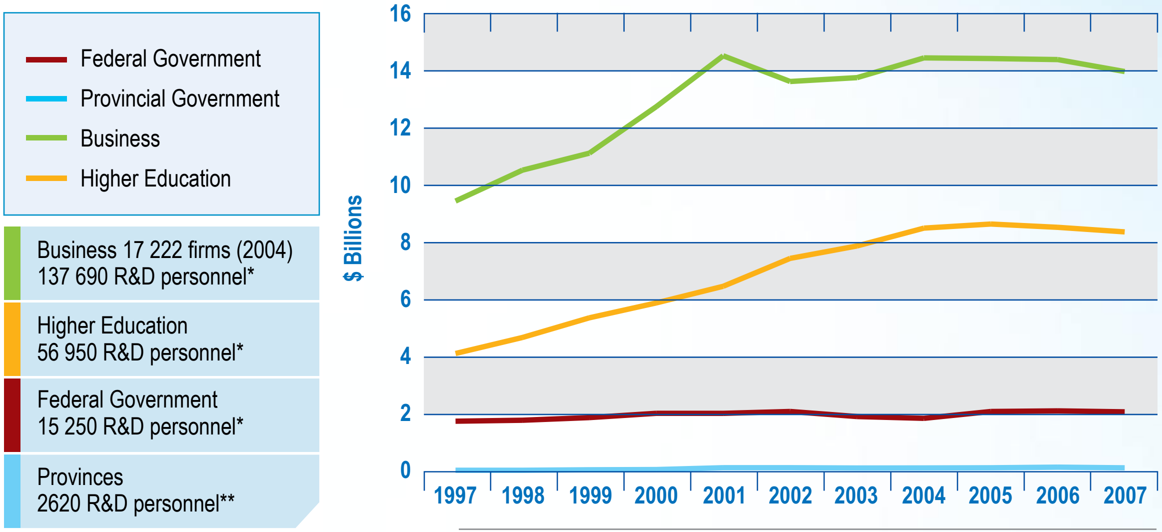
Figure 2: National R&D Expenditure (GERD); % Share of GDP (1996 and 2006)



Source: OECD, Main Science and Technology Indicators, 2008.

In 2006, R&D expenditures accounted for some 1.9 percent of Canada's GDP. This share was around 18 percent higher than the share in 1996. Over the same period, the average share of R&D expenditures in the G-7 grew from around 2 percent to around 2.2 percent. Figure 2 shows that while Canada is catching up, R&D as a share of Canadian GDP still lags behind the G-7 average, and this share is substantially behind the share in leading innovative countries such as Finland, South Korea and the U.S.[17] Increasing Canada's research intensity and fostering an innovative economy will require concerted and coordinated efforts by the three principal Canadian R&D performing sectors: the private sector, the higher education sector and government. Figure 3 shows the growth of R&D spending by each of these sectors from 1997–2007.

Figure 3: Gross Domestic Expenditures on R&D by Performing Sector, 1997–2007 (Constant 2002 Dollars)



* Statistics Canada, "Science Statistics" vol. 32, no. 1, May 2008. Cat. No. 88-001.

** Includes provincial research organizations.

Source: Statistics Canada, CANSIM table 385-001, Dec. 17, 2008.

Figure 2, on national R&D expenditures as a percentage of GDP, shows that Finland and Korea both had very strong levels of R&D/GDP growth from 1996–2006. In both of these countries, business-performed R&D as a share of GDP grew considerably over this period, contributing 75 percent and 80 percent, respectively, of the total national increase in R&D spending. In the U.S., growth in business R&D contributed to 68 percent of the total growth in R&D over this period. The story was similar in Germany, another G-7 country, where growth in business R&D accounted for 76 percent of total national R&D growth from 1996–2006. In Canada, growth in business R&D was responsible for just over half of the growth in total R&D over this period: business performance of R&D grew from just under $8 billion in 1996 to just over $14 billion in 2006.[18] However, Canadian university R&D had the fastest growth rate over this period.

While R&D is used as a proxy for innovation, it does not tell the whole story. According to Statistics Canada, in 2005, 34 percent of manufacturing companies with 20 or more employees in Canada performed R&D, while more than 60 percent engaged in innovation.[19] This suggests that many companies are bringing value to the market by using knowledge that does not necessarily come from R&D. Innovation strategies, therefore, should take account of knowledge gained through learning by doing and using, and through contacts and collaboration outside the firm.

[17] OECD, Main Science and Technology Indicators, 2008/1.

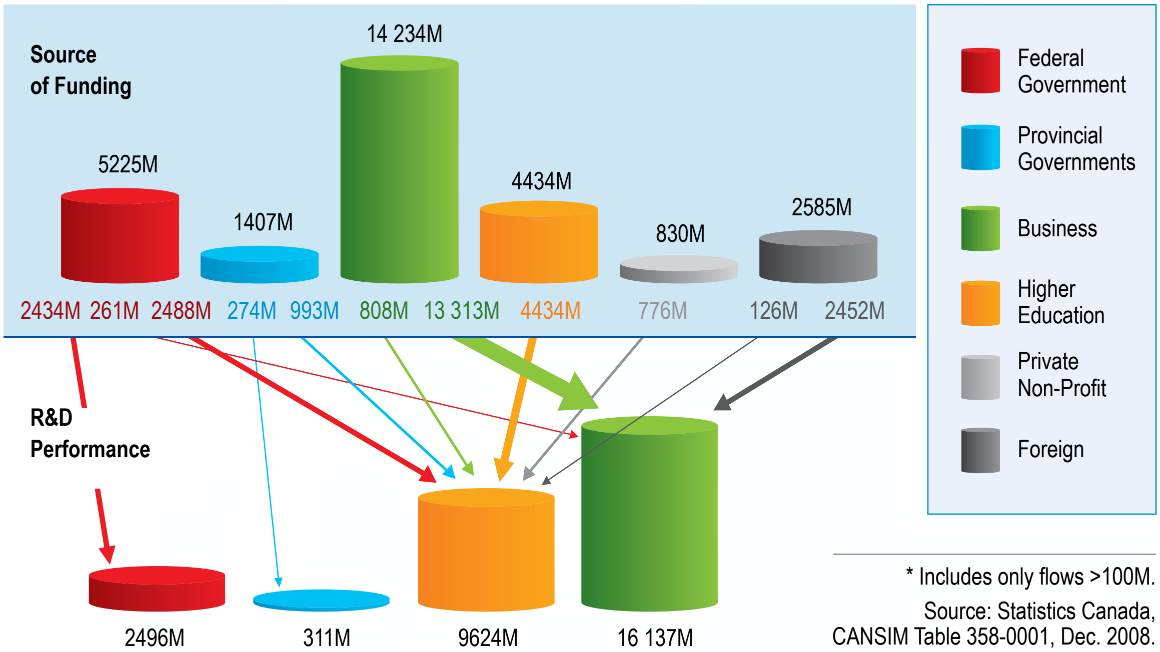
[18] Statistics Canada, CANSIM table 358-0001, *Gross domestic expenditures on research and development, by science type and by funder and performer sector*, Downloaded December 2008.

[19] Statistics Canada, *Survey of innovation, logging and manufacturing industries, percentage of innovative plants, occasional*, CANSIM table 358-0062; Statistics Canada, Custom data request, Business Register enterprise counts 20 or more employees December 1997 to 2007 and Research and Development in Canadian Industry, 2008 frozen base with firms performing R&D counts to 2005.

3.6 Canada's Principal Research and Development Performing Sectors and their Roles

No one sector of the economy or society is solely responsible for supporting Canada's science, technology and innovation capacity. Figure 4 shows R&D funding and performance are undertaken by various partners in the three principal performing sectors and other supporting agents such as private not-for-profit organizations.

Figure 4: Major Flows of R&D Funding in Canada, 2006*



* Includes only flows >100M.

Source: Statistics Canada, CANSIM Table 358-0001, Dec. 2008.

In Canada, the major performing sectors are:

- ***Private Sector:*** Private entrepreneurs represent the single largest R&D sector. They range from research giants to small and medium-sized enterprises. Private entrepreneurs bring new innovative products and services to the marketplace and enhance their competitive advantage by introducing new efficiencies through advanced, and at times, revolutionary processes and systems. In 2006, this sector performed $16 billion, or some 56 percent, of Canada's total R&D.

  R&D expenditures by the principal industrial sectors in Canada were: agriculture, forestry, fishing and hunting ($115 million); mining, oil and gas extraction ($578 million); utilities ($318 million); construction ($69 million); manufacturing ($8.6 billion); and services ($6.5 billion). The manufacturing sector and the services sector accounted for the vast majority of all R&D expenditures in Canada. Within these aggregated sectors, however, a number of industries were responsible for a disproportionately large share of the total. In 2006, the six leading industries performing R&D represented almost half (46 percent) of all business expenditure on R&D. These industries were information and cultural industries ($1.7 billion); communications equipment ($1.5 billion); scientific R&D services ($1.2 billion); computer system design and related services ($1.2 billion); pharmaceuticals and medicine ($1.1 billion); and aerospace products and parts ($857 million).[20]

  Current indicators of R&D performed do not reflect purchases of equipment for innovation or new processes. For example, application of a new fertilizer would not be captured under agricultural R&D, although the development of the fertilizer would be captured under R&D spending in the chemicals industry. Research into automated lumber

[20] Statistics Canada CANSIM table 358-0024, *Business enterprise research and development (BERD) characteristics by industry group based on the North American Industry Classification System (NAICS)* downloaded December 23, 2008. Note: Aerospace Products and Parts Manufacturing figure is R&D spending for 2005 (2006 not available).

processing equipment would not be captured under forestry but would be captured under one of the machine or instruments industries. Adoption of this equipment would only be reflected under the lumber industry's machinery and equipment investments and in innovation surveys.

Many Canadian high-tech companies are niche-oriented and supply services and products for various industrial vertical markets both in Canada and abroad. In the computer systems design and related services industry, for example, companies can produce custom software solutions to support the financial services industry or the natural resources sector. Many Canadian companies produce advanced equipment for process monitoring and control in manufacturing. R&D in some industries can support and lead to process innovations in other industries as new software and industrial products are adopted.

The scientific R&D services industry includes companies that undertake R&D activities in Canada. R&D captured under this heading might be more appropriately classified under a range of other technological fields. For example *fabless* semi-conductor companies (companies that undertake research and design but contract out manufacturing) are often classified in this industry. As outsourced and offshore manufacturing grows, the share of total expenditures recorded under the R&D services industry will likely increase.

Large companies disproportionately undertake research and development expenditures. In 2004, 17 222 companies reported performing R&D in Canada. Smaller companies, with less than $10 million in revenues, accounted for 81 percent of all performers, but only 22 percent of all R&D performed. By contrast, the largest companies, those with revenues of $400 million or more, accounted for only 1 percent of all R&D performers but 42 percent of all R&D performed.[21] Dr. Douglas Barber and Dr. Jeffrey Crelinsten, using data from Statistics Canada and RE$EARCH Infosource Inc., found that from 1994 to 2001, just 228 companies in Canada could be considered *R&D Leaders*. These companies invested between 3 percent to 50 percent of sales revenue on R&D and had R&D spending of $3 million or more each year.[22]

- ***Universities and Colleges:*** There are some 400 universities and colleges in Canada.[23] These institutions fulfill multiple roles in Canada's innovation system. They prepare the next generation of highly skilled and qualified personnel, and drive innovation through the basic and applied research they conduct. They also spur collaboration through national and international networks and partnerships. Many of Canada's major science investments like the Canadian Light Source Inc. and NEPTUNE Canada, are based at universities. In 2006, the Canadian higher education sector performed some $10 billion, or 34 percent of Canada's total R&D.[24]

- ***Private Not-for-Profit Organizations:*** These organizations and research institutions are increasingly playing a role in supporting the creation of critical masses of expertise. Their public profile helps bring Canadian R&D efforts to individual Canadians. The funds and philanthropic endeavours mobilized by these organizations demonstrate tangible support by individual Canadians for R&D. Health charities, for example, fund major research initiatives focused on specific diseases or health care demands. Others focus on the needs of industry and work at solutions or coordinate research activities for sector-wide or cross-sector research challenges. In 2006, the private not-for-profit sector performed some $125 million, or 0.4 percent of Canada's total R&D and funded $830 million in R&D.[25]

- ***Public Sector:*** Municipal, provincial and federal governments establish policies and incentive structures to encourage R&D. The public sector conducts research to meet its own regulatory requirements and undertakes fundamental research in areas of local, regional or national importance. The public sector can also help coordinate the research activities of the other players by creating opportunities for competitors to collaborate for their mutual benefit. While government R&D is an important feature of Canada's innovation landscape, the principal financial contribution of government to research in Canada comes in the form of funding for R&D, which is carried out by the other sectors.

The Government of Canada directly funded about $5 billion of R&D performed in Canada in 2006. Half of this $5 billion (around 8.7 percent of total Canadian R&D) was carried out in Government of Canada institutions and labs. The remainder of about $3 billion for R&D was performed by the higher education, business enterprise and private not-for-profit sectors. Provincial governments funded some $1.4 billion in R&D expenditures in 2006, some $993 million of which was in the form of direct R&D funding to the higher education sector.[26]

[21] Statistics Canada, *Industrial Research and Development: Intentions 2007*, September 2008, Cat. no. 88-202-X, p. 17.

[22] Dr. H. Douglas Barber and Dr. Jeffrey Crelinsten, *The Economic Contribution of Canada's R&D Intensive Enterprises 1994–2001*, RE$EARCH Infosource Inc., March 2004, p. 3 accessed at (http://www.impactg.com/pdf/economiccontribution.pdf).

[23] Statistics Canada, *Register of Postsecondary and Adult Education Institutions*, http://www27.statcan.ca/IP_Internet/English/Browse/EntryForm.asp. Downloaded January, 2009. Figure is sum of categories "University and degree granting institutions," and "colleges and institutes."

[24, 25, 26] Statistics Canada, CANSIM table 358-0001, downloaded December 17, 2008.

4. Digest of Key Indicators

The Science, Technology and Innovation Council has selected a number of indicators particularly relevant to examining and explaining Canada's science, technology and innovation performance. Some indicators were chosen because they were internationally comparable, and updated annually, allowing us to compare how we are doing against our global competition. Others allow us to monitor Canadian-specific trends and issues. In considering these rankings, it is important to remember that the size of the Canadian economy ranks 9th and our population ranks 12th in the OECD.

The task of analyzing and understanding the importance of science, technology and innovation and its impact to our economy and our living standards needs good, easily available data, and indicators that can help us track our performance against other countries. Other countries are already well on their way to tackling this challenge. For example, the National Endowment for Science, Technology and the Arts in the United Kingdom (U.K.) is developing a new Innovation Index, designed, among other things, to better measure the contribution of innovation to productivity growth, and measure firm-level innovation performance in six priority sectors of the U.K. economy.[27] The U.S. is currently piloting its first national innovation survey, which will allow it to measure innovation by geography, industry and size of firm.

4.1 Canada's Business Innovation Indicators

Canadians' living standards depend on ensuring that Canadian businesses are globally competitive, by turning new knowledge into new goods, services, processes and business models that can be sold profitably around the world.

Productivity, Economic Growth and Innovation

Analyses by the Council of the Canadian Academies,[28] Statistics Canada,[29] and the Centre for the Study of Living Standards[30] have shown the critical link between Canadian productivity, economic growth and innovation. Innovation drives productivity growth in three main ways: the innovation embedded in technically advanced capital equipment; the development of new sources of value; and improvements in the organization of work. The gap in productivity and productivity growth between Canada and our main trading partner, the U.S., has been well documented. Labour productivity growth in Canada has been slower than in the U.S. for more than two decades and has become much worse in this decade. Canada's productivity growth has also been slower than most OECD countries — we rank 15th out of 18 comparable countries. Labour productivity growth increases when workers have more or better capital machinery and equipment (*capital intensity*) and when labour, capital and other inputs to the production of goods and services are combined more effectively (often referred to as multifactor productivity or MFP). MFP is probably the best measure that we have on the impact that growth in innovation has on the economy. MFP measures broadly, over long periods of time, the impact of "better organization of work, improved business models, the efficient incorporation of new technology, the payoff from R&D and from collaboration with innovation partners."[31] MFP is able to capture forms of innovation that indicators such as R&D intensity do not.

Figure 5 shows the sources of business sector productivity growth in Canada and the U.S. Slower MFP productivity growth has been by far the most important source of the growing gap between Canadian and U.S. labour productivity levels. As the Council of the Canadian Academies notes, "Since Canada's weak productivity performance over the past two decades is due primarily to low MFP growth, it follows that Canada's productivity problem is rooted in weak business innovation performance."[32] It has also been well documented[33] that low productivity growth directly affects our standard of living.

[27] www.innovationindex.org.uk The six priority sectors are legal services, consultancy services, accountancy services (as part of knowledge intensive business services); software and IT services; architecture and design (as part of creative services); aerospace, automotive (as part of high-value manufacturing); construction; and energy production.

[28] *Innovation and Business Strategy: Why Canada Falls Short.* A report by the Expert Panel on Business Innovation in Canada, Council of Canadian Academies, 2009.

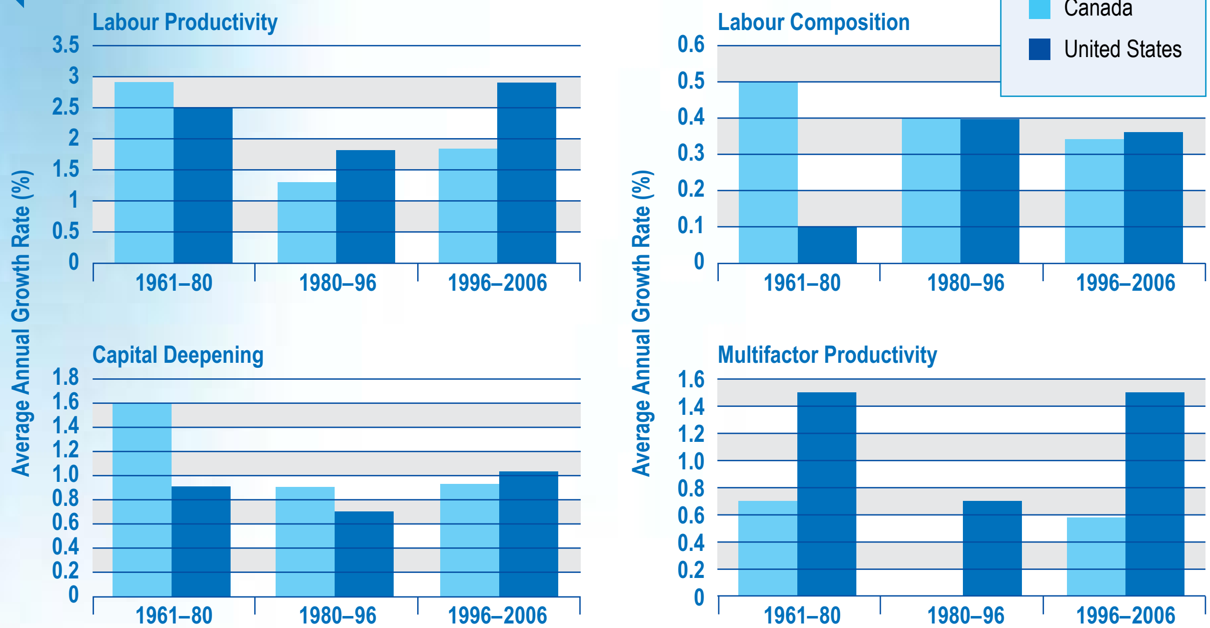
[29] John R. Baldwin and Wulong Gu, *Long-Term Productivity Growth in Canada and the United States — 1961 to 2006, The Canadian Productivity Review*, Statistics Canada, Cat. no. 15-206-XIE, No 13, August 2007.

[30] Centre for the Study of Living Standards ICT database, available at http://www.csls.ca/data/ict.asp.

[31, 32] *Innovation and Business Strategy: Why Canada Falls Short.* A report by the Expert Panel on Business Innovation in Canada, Council of Canadian Academies, 2009.

[33] See work by the Centre for the Study of Living Standards at http://www.csls.ca.

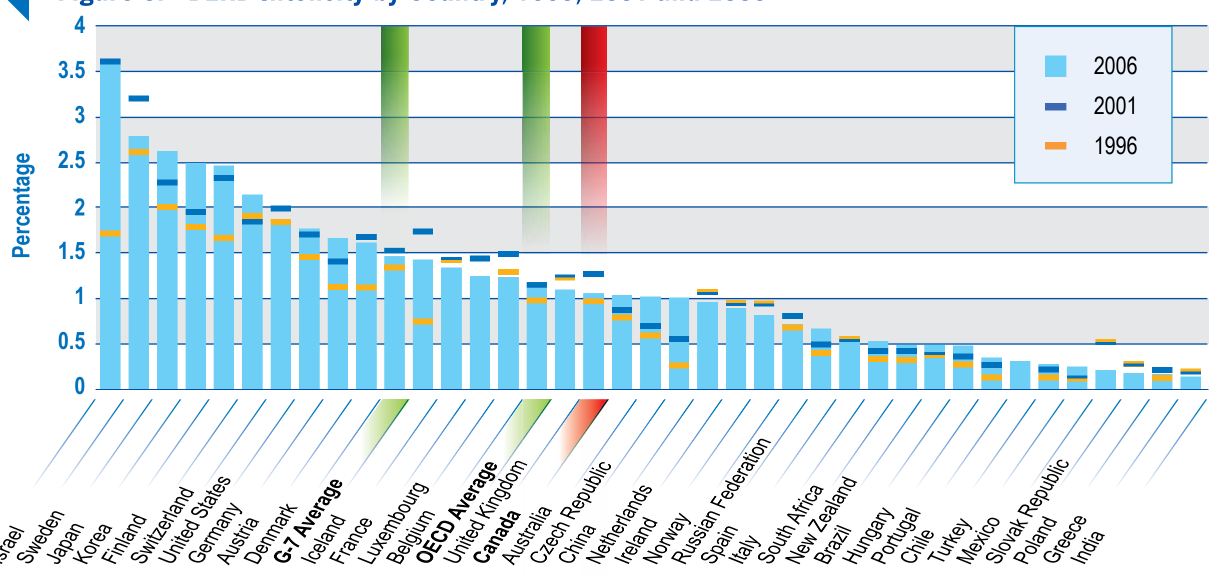
Figure 5: Sources of Business Sector Productivity Growth: Canada and the U.S.



Business Expenditure on Research and Development

While BERD captures a narrower range of activities than is captured by innovation surveys, it is a good indicator of capturing how important innovation is for business strategy. Expressing BERD as a percentage of GDP indicates the intensity in which businesses invest in R&D and allows us to compare economies of different sizes. In 2006, the last year for which internationally comparable data are available, Canada ranked 15th in the OECD (see Figure 6), and business R&D intensity in Canada has been decreasing since 2002.[34] Compared to our major competitor in the North-American economic space, the U.S., Canadian companies invest much less on R&D as a percentage of GDP. In 2006, U.S. firms invested 1.8 percent of GDP on R&D, compared to only 1.06 percent in Canada. We are in the middle of the OECD pack of 30 countries, but only sixth in the G-7.

Figure 6: BERD Intensity by Country, 1996, 2001 and 2006



Source: OECD, Main Science and Technology Indicators Database, April 2008.

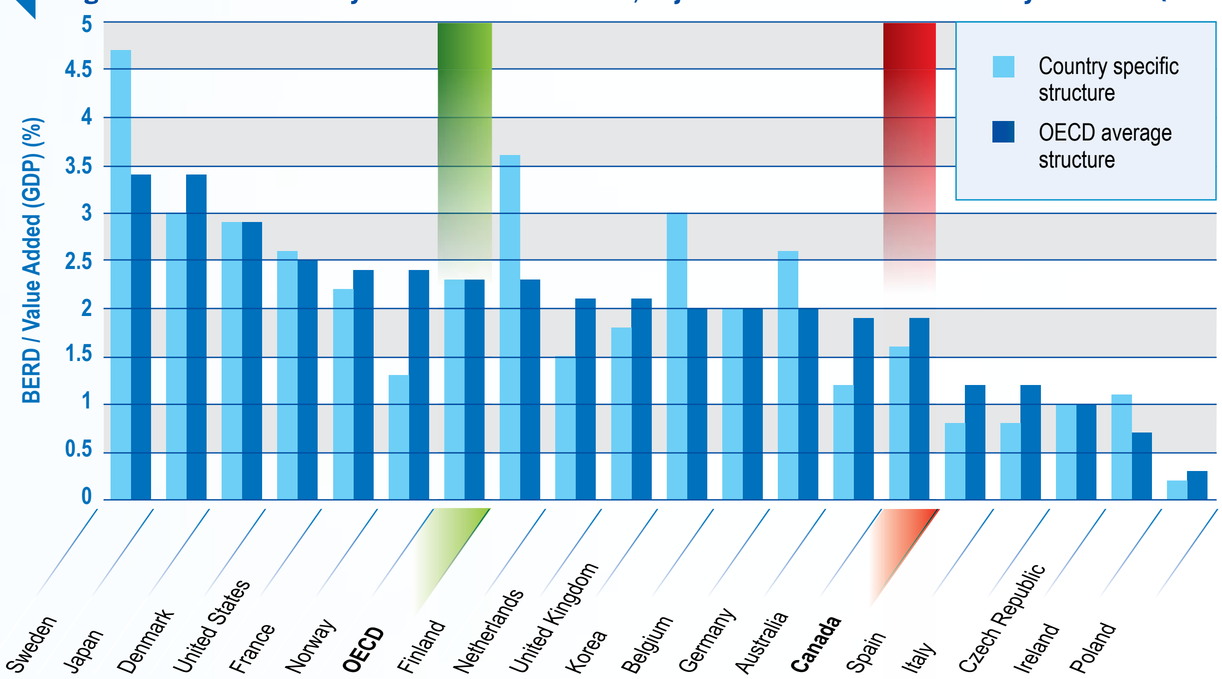
[34] In Canada, BERD as a percentage of GDP (i.e. BERD intensity) was 1.29 percent in 2001 and 1.06 percent in 2006. In comparison, the average BERD intensity in the OECD was 1.57 percent in 2001 and 1.56 percent in 2006. Canada's drop in BERD intensity was similar to that in the United States (BERD intensity in the U.S. was 2.0 percent in 2001 versus 1.84 percent in 2006) but Canada's drop in BERD intensity from 2001 to 2006 was the biggest in the G-7.

In 2006, total BERD in Canada reached $16.1 billion, with the manufacturing ($8.6 billion) and services ($6.5 billion) sectors accounting for 93 percent of this total. The six leading industries[35] performing R&D during this period represented almost half (46 percent) of all BERD in Canada.[36]

Previous studies[37] have shown only a few industrial sectors account for the low aggregate business R&D intensity in Canada relative to the U.S. In these studies, almost the total gap is accounted for by low business R&D intensity in the services sector and the motor vehicle industry.[38] However, sectoral differences in business R&D intensity and the reasons for differences between comparable Canadian and U.S. industry sectors are not particularly well understood.

Canada's low ranking in BERD intensity is not the result of our industrial structure. A recent study by the Australian government's Productivity Commission removed the influence of industrial structure from BERD intensity rankings, by constructing an "average OECD industry structure," and adjusting BERD intensity data in each OECD country to reflect the average OECD industry structure. The results of this are shown in Figure 7.

Figure 7: BERD Intensity Across OECD Countries, Adjusted for Variations in Industry Structure (2002)



Source: Productivity Commission 2007, Public Support for Science and Innovation, Research Report, Productivity Commission, Canberra.

35 Industries included information and cultural industries ($1.7B), communications equipment ($1.5B), computer system design and related services ($1.2B), scientific R&D services ($1.2B), pharmaceutical and medicine manufacturing ($1.1B), and aerospace products and parts manufacturing ($857M — 2005 data).

36 Statistics Canada, *Industrial Research and Development, 2004 to 2008*, Catalogue no. 88-001-X, vol. 32, no. 5, September 2008; CANSIM tables 358-0001, 358-0024.

37 Aled ab Iorwerth, *Canada's Low Business R&D Intensity: the Role of Industry Composition*, Government of Canada, Department of Finance, Working Paper 2005-03, March 2005; Surendra Gera, Francois Rimbaud, Kellie Fong, "An Overview of the Performance of the Canadian Innovation System," Government of Canada, Department of Industry, mimeo (March 19, 2007).

38 Canada's low R&D investments in the auto sector reflect the integrated nature of the North-American auto sector. While the service sector in Canada conducts little R&D, its record in the broader context of innovation is better. Innovation in services includes process and product innovation and has more of an emphasis on changes in organization design, business models, and market development.

This illustrates that after the influence of industrial structure is removed, Canada's overall BERD intensity increases a little, but we actually drop in the adjusted OECD BERD intensity rankings. In 2002, using a country specific industry structure (i.e. how the OECD normally reports these data) Canada's BERD intensity was 1.6 percent — good enough to rank 12th in the OECD that year. Weighing Canada's BERD expenditures using an "average OECD industry structure," our BERD intensity, according to the Australian government's Productivity Commission, was 1.9 percent, but we dropped to 13th in the adjusted OECD BERD intensity rankings.

The trend in BERD intensity is downward since 2002. While total BERD dipped slightly in 2002 and 2003 from 2001 levels, by 2004 they had recovered to be greater than 2001 levels, and have increased slowly since then. However, the rise in total BERD in Canada has not kept pace with GDP growth, which is why BERD intensity is down since 2002.

Percentage of Total Research and Development Performed by Business

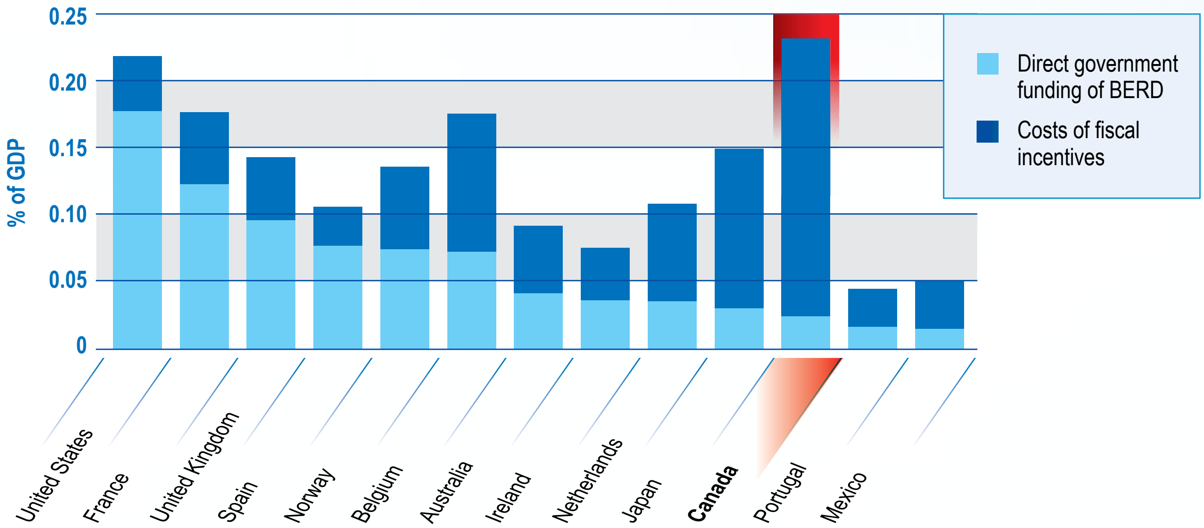
It is evident that compared to other OECD countries, business R&D in Canada is a comparatively smaller portion of total R&D performed by all sources (i.e. the gross expenditure on R&D [GERD]). In 2006, Canada's business sector performed 55 percent of all R&D, compared to: 77 percent in Japan; 70 percent in the U.S. and Germany; 63 percent in France; and 62 percent in the U.K.[39]

R&D is therefore performed to a much greater degree by the business sector in other countries. Since the R&D performed by business is more likely to be *closer to the market* (i.e. more *development* than *research*) this may have an impact on Canada's ability to turn research into new products, services, processes and business models that are sold globally. Compared to our major competitors, more of our R&D is performed by universities and colleges. Most of this is more basic research, farther away from being turned into profitable market opportunities and results.

Government Support of Business Research and Development

Governments at different levels in Canada encourage business R&D. Federal and provincial governments provide assistance through government programs and arm's-length foundations. The May 2007 Government of Canada S&T Strategy, *Mobilizing Science and Technology to Canada's Advantage*, suggested that aligning federal programs and activities could result in more effective support. The OECD has begun to compare total direct versus indirect support by government of business R&D for some countries. This work in Figure 8 shows that when direct support is added to the value of indirect support of business R&D, for the 13 OECD countries for which data are available, Canada has the richest government support of business R&D, as a percentage of GDP, just edging out the U.S.

Figure 8: Direct and Indirect Government Funding of Business R&D and Tax Incentives for R&D (2005 or Latest Available Year)



Source: OECD, based on national estimates (NESTI R&D tax incentives questionnaire), some of which may be preliminary.

[39] OECD, Main Science and Technology Indicators, 2008/1.

Canada's government support of business R&D in 2005 was equal to 0.23 percent of GDP, just ahead of the U.S. where government support of business R&D was equal to 0.22 percent of GDP. While the total (i.e. indirect plus direct) government support of business R&D is similar, 90 percent of Canadian support was for indirect measures (the business R&D tax credit), while 80 percent of government support in the U.S. was for direct government funding of BERD, and only 20 percent of U.S. government support of business R&D went for indirect measures.

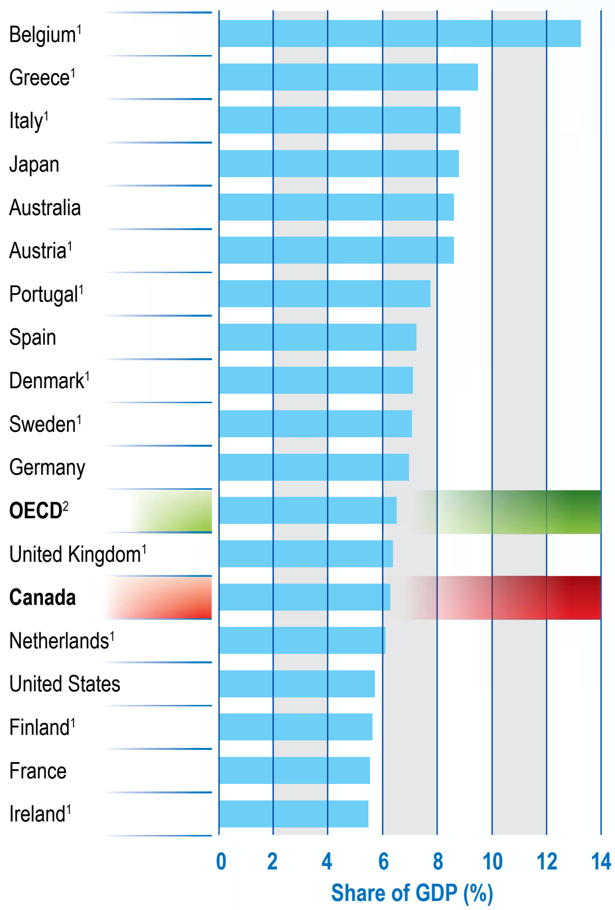
Canada's Scientific Research and Experimental Development (SR&ED) tax credit is the single largest financial support given to businesses in Canada to conduct R&D. In 2007, nearly $3.7 billion in assistance was given to Canadian firms.[40] Compared to other countries, Canada's tax credits for R&D are one of the highest in the world for small and medium-sized enterprises, but other countries, notably economies such as Mexico, France, China, India and Singapore, offer much higher tax credits for R&D performed by large firms.[41]

Business Investment in Machinery and Equipment

There is considerable research that shows that a firm's ability to create new products, services, processes and business models is strongly related to its capacity to absorb and use new ideas. Much of that capacity is related to the skill level of a firm's workforce, a subject we examine in Section 4.3 *Talent Indicators*. In addition, much of that absorptive capacity is built through the purchase and use of new machinery and equipment (M&E), which incorporates the latest knowledge and technologies. In turn, the use of the latest M&E improves a country's productivity.

Business investment in machinery and equipment is particularly important in Canada, since Canada's business investment gap with the U.S. has been due to lagging M&E investment, which goes beyond ICT assets. Research suggests that, "when industry structure is taken into account for the M&E asset class, most industries of Canada's business sector are less capital intensive than that of the U.S. In the case of non-ICT M&E, there is a small deficit of about 12 percent. The deficit is more pronounced for ICT investments — some 33 percent."[42] Manufacturing plants that introduce advanced technologies to the market in Canada are most likely to be technology purchasers, with more than 55 percent of plants choosing this method. There is considerable *user-driven* innovation taking place, however, as 42 percent of firms either modified the technology they purchased or developed it themselves in-house.[43]

Figure 9: Investment in Machinery and Equipment, 2004



1 2003.

2 excl. Greece, Australia and Austria.

Source: OECD Science, Technology and Industry Scoreboard, 2007.

40 Government of Canada, Department of Finance, Tax Expenditures and Evaluations, 2008, Table 2, "Corporate Income Tax Expenditures," page 26.

41 OECD, Science, Technology and Industry Outlook 2008, based on Jacek Warda, *Generosity of Tax Incentives*, presentation at the TIP Workshop on R&D Tax Treatment in OECD Countries: Comparisons and Evaluations, Paris, 2007, 10 December 2007 accessed at http://www.oecd.org/dataoecd/40/33/40024456.pdf.

42 John Baldwin, Anthony Fisher, Wulong Gu, Frank C. Lee and Benoit Robidoux, *Capital Intensity in Canada and the United States, 1987 to 2003, The Canadian Productivity Review*, 2008, Statistics Canada Catalogue no. 15-206-X, no. 018, July 2008. p. 41.

43 Statistics Canada, Follow-up to the Survey of Advanced Technology 2007.

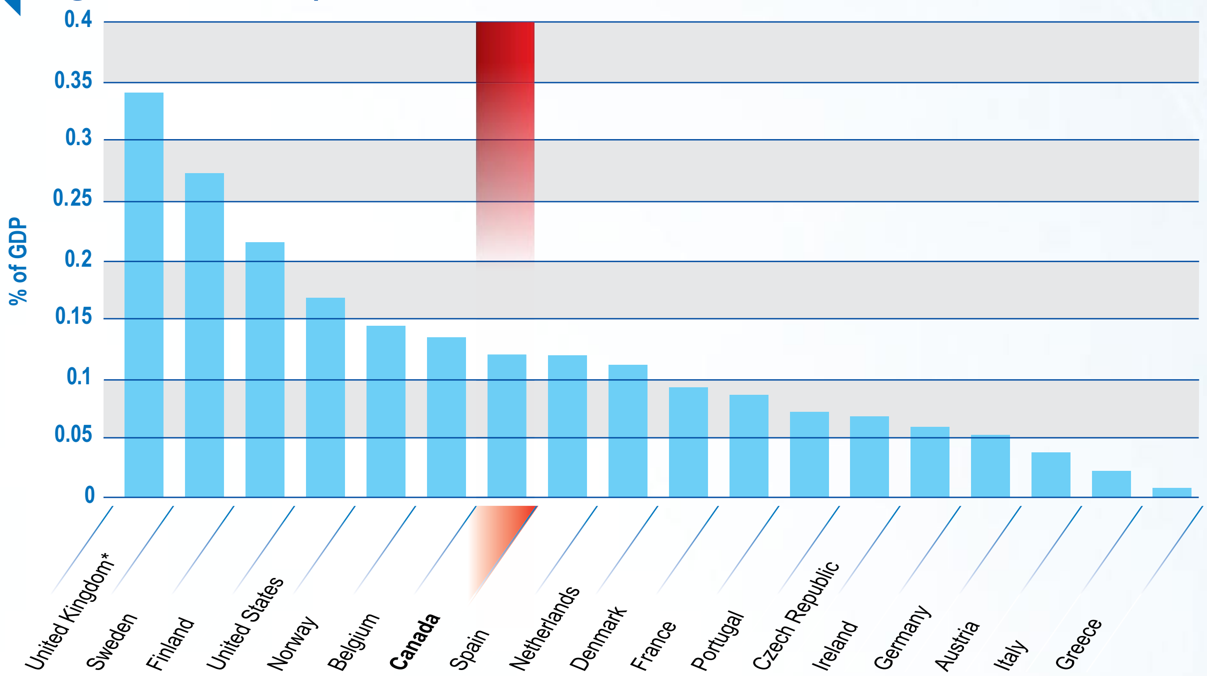
Canada again places in the middle of the OECD pack for business investment in machinery and equipment as a share of GDP. As shown in Figure 9, in 2004, we ranked 13th in the OECD, the last year for which internationally comparable data are available. Analysis by the Council of Canadian Academies, using data from the Centre for the Study of Living Standards ICT database, shows that even as the Canada–U.S. exchange rate (i.e. US$ per C$) was increasing rapidly beginning in 2002, annual M&E investment as a percent of GDP did not increase.[44]

Even though imported machinery and equipment became appreciably cheaper due to the approximate 37 percent rise in the value of the Canadian dollar from February 2002 to January 2008 (important since about two-thirds of the total value of Canadian purchases of M&E are imported), overall purchases of M&E have only kept pace with the growth in Canada's GDP. Given the importance of new machinery and equipment, which embodies the latest innovation and contributes greatly to increased productivity, federal budget initiatives in 2007 and 2008 increased the capital cost allowance (CCA) for most machinery and equipment used in manufacturing and processing from a 30 percent declining balance CCA rate to a 50 percent straight-line CCA rate. This has significantly reduced the after-tax cost of most machinery and equipment in Canada.

Venture Capital Investment

Less than two percent of total small and medium-sized business financing in Canada comes from venture capital (VC). Other sources of capital investment are far bigger. In 2007, the most recent year for these data, 53 percent of business financing came from domestic banks, 16 percent from other banks, 10 percent from credit unions and Caisses Populaires, 11 percent from finance companies, and 8 percent from insurance companies.[45]

Figure 10: Venture Capital Relative to GDP (2007)



* For United Kingdom, seed/start-up type VC is excluded for 2006.

Source: ICE. 2008. Quality Assessment of Entrepreneurship Indicators Version 4.

44 *Innovation and Business Strategy: Why Canada Falls Short.* A report by the Expert Panel on Business Innovation in Canada, Council of Canadian Academies, 2009, using data from the Centre for the Study of Living Standards ICT database, available at http://www.csls.ca/data/ict.asp.

45 Statistics Canada. *Survey of Suppliers of Business Financing, The Daily*, December 5, 2008.

However, for some industries, particularly information technology, telecommunications, biotechnology and environmental technologies, VC is essential to firm growth, so tracking our VC performance is very important. There are differences in results depending on which source of VC data is used, but the International Consortium on Entrepreneurship (ICE) provides internationally comparable data. According to these data, shown in Figure 10, Canada ranks seventh among the countries compared in VC investment as a percentage of GDP.

Canadian firms attract a large number of VC investments, but the average size of each deal is much smaller than our major competitors, particularly those in the U.S. In 2006, according to the ICE data, the average VC deal size in the U.S. (the world leader) was three times the average VC deal size in Canada, which ranks 10th in the world. One possible reason for this difference is that VC funds in Canada on average are much smaller than those in the U.S. In addition, much more of our VC investments are in seed or start-up companies (as opposed to expansion or late-stage investments). The ICE 2006 data showed that about 35 percent of total VC investments in Canada were in seed or start-up companies, compared to less than 10 percent for the U.S. Canada's VC investments are also highly concentrated by sector. Eighty percent of Canada's VC investments in 2005 went to only three sectors: communications, information technology and health/biotechnology (almost evenly distributed between these three sectors). The OECD average for these three sectors was only 40 percent of total VC investment.[46] It is important to note that in 2005, the U.S. was even more concentrated in these three sectors, accounting for 88 percent of total VC investment.

Venture Capital's Crucial Role: SiGe Semiconductor

For many high-tech companies, venture capital is the lifeblood of growth. Without readily available expansion capital, even highly inventive companies may miss the chance to capitalize on growing markets and new opportunities for commercialization.

SiGe Semiconductor has been able to tap local, national and global venture capital markets to bring new products to market. SiGe, like many Canadian semiconductor companies, is 'fabless' — meaning they undertake only the research and design aspects of producing semiconductors, and contract out the manufacturing. From its inception as a spinoff from the National Research Council Canada in 1996, SiGe Semiconductor has grown into the world's leading provider of radio-frequency semiconductor solutions in their niche. The company provides wireless networking solutions for some of the world's largest information and communication technology firms, including Apple, Dell and Nintendo. Successive rounds of venture capital funding have been crucial to this growth, and SiGe's network of venture capital partners continues to expand. Most recently, South Korean electronics giant Samsung joined established partners such as TD Capital Technology Venture and 3i Venture Capital in financing SiGe's latest expansion plans.

[46] OECD, Science, Technology and Industry Outlook 2008, Figure 1.26, StatLink: http://dx.doi.org/10.1787/451076733881.

There is also a large comparative difference in the percentage of VC funds raised by type of investor. In Canada, 58 percent of capital raised by VC funds was invested by individuals in so-called *retail* VC companies. In contrast, most VC funds in the U.S. in 2003 were raised from pension funds (42 percent) and banks and insurance companies (25 percent). In Canada, in 2006, only 10 percent of capital raised by VC funds came from pension funds and only 2 percent from banks and insurance companies. This difference occurs in part because, unlike the U.S., Canada has tax credit government programs, such as the Government of Canada's Labour-Sponsored Venture Capital Tax Credit, that encourages individuals to make investments in retail VC companies.

Net returns to VC investors in Canada have been anemic, particularly when compared to the net return to VC investors in the U.S. Analysis by the Council of Canadian Academies — using data from the Canadian Venture Capital Association and the National Venture Capital Association in the U.S. — shows, for example, that in the U.S. the net return on the previous 10 years, after averaging around 26 percent from 2001–03, declined to 18.3 percent in 2007. In contrast, the net 10-year return to VC investors in Canada, was 13.1 percent in 2001, declined to 6.1 percent in 2002, and declined further to 1.7 percent in 2007.[47]

Percentage of Total Sales from Innovative Products

Another useful indicator of how innovative Canadian companies are, and the extent to which they use new technology and innovation as an important part of their business strategy, can be found by looking at the share of sales from product innovations (i.e. new products introduced within the last three years) as a percentage of the firm's total sales. Continuing work by the OECD looks to connect firm micro data on sales to their responses to innovation surveys. Preliminary work on 14 countries[48] shows that only 9 percent of Canadian manufacturing firms' total sales come from sales of new innovative products. This compares to almost 15 percent in Finland (the leader in this grouping of countries), and almost 13 percent in the U.K., but is considerably greater than Japan (about 5 percent) and Australia (about 4 percent). The U.S. does not yet have an innovation survey, and therefore is not among the group of countries compared.[49]

Turning Local Advantage to Global Competitiveness

In the early 1990s, John Risley, President and CEO of Nova Scotia based Clearwater Fine Foods Incorporated, a leading company in the global seafood industry, was interested in Omega-3s because of their potential treatment for heart disease in humans. He purchased a small company in Cape Breton, Nova Scotia that distributed Omega-3 fatty acid products to veterinary hospitals throughout Canada. In 1997, Risley launched Ocean Nutrition Canada Limited (ONC) with headquarters in Bedford, Nova Scotia, research facilities at Dalhousie University in Halifax, and a plant in Mulgrave, Nova Scotia to refurbish and produce purified Omega-3 EPA/DHA oil.

ONC discovered a breakthrough technology that transformed fish oil into a powder finer than flour. This technology, now known as Powder-loc™, was unique in the industry because it could withstand almost any baking industry process and had no taste or smell properties. It could successfully be added to products such as baked goods, milk, yogurt, juice and nutrition bars, among others.

Since ONC opened in 1997, its growth has been tremendous. In 1997, there were only 4 employees, and now ONC is over 300 strong. ONC's reputation as a global leading supplier of Omega-3 EPA/DHA ingredients to the dietary supplement and healthy food markets has increased. They now have clients in North America, Asia, Europe and Australia.

47 *Innovation and Business Strategy: Why Canada Falls Short.* A report by the Expert Panel on Business Innovation in Canada, Council of Canadian Academies, 2009.

48 Canada, Finland, Sweden, United Kingdom; Belgium, Luxembourg, Denmark, Austria, Germany, Netherlands, France, Japan, Norway and Australia. (OECD: DSTI/EAS/STP/NESTI (2008) 14).

49 The United States is currently conducting its first-ever innovation survey, which will allow it to measure innovation by geography, industry and size of firm.

The Payoff: Firms that Perform More Research and Development and Innovation Have Greater Sales and are More Productive

New joint academic/Industry Canada research[50] has provided strong evidence of the payoff from increased innovation expenditures by firms. This work, which compares 17 OECD countries and Brazil, shows that firms that have higher innovation expenditures (including for example, R&D and M&E for innovation) have greater sales of innovative products, and are also more productive (greater overall sales per employee). The results were found to be true even when they controlled for the share of university degree holders in the workforce and the size of the firm.

Innovative Spirit Soars at CAE

In February 2009, Canada marked the 100th anniversary of its first airplane flight. Our aerospace industry has made great strides since that cold February day in 1909 when J.A.D. McCurdy took to the sky in a small plane called the *Silver Dart*. Thanks to investment partnerships with government and innovative technologies, Canada is recognized as a world leader in aerospace.

CAE Inc. is a cornerstone of this success. From its humble beginnings in 1947 with 18 employees in Saint-Hubert, Quebec, CAE has flourished into a world-leading provider of simulation and modelling technologies and training services for the civil aviation industry and defence forces around the globe. Throughout its history, CAE has continuously set industry standards and contributed to the safety of aviation. The company has simulated almost every modern airliner for both major and regional carriers, as well as many of today's business jets, and has developed more prototype simulators than any other company. CAE is also one of the world's leading suppliers of military full-mission simulators. In addition, through its global network of 27 civil aviation and military training centres, CAE trains more than 75 000 crewmembers yearly. With annual revenues exceeding C$1.4 billion, CAE employs approximately 7000 people at more than 75 sites and training locations in 20 countries.

How Companies Innovate is Changing Rapidly: The Rise of Open Innovation

As global competition intensifies, and the cost and risk of developing new technologies and services to meet that competitive challenge increases, companies around the world are finding that a *go it alone* strategy for technology development and innovation is no longer effective. More and more, they are turning to *open innovation,* that is sources outside their companies for new product and service ideas that can be further developed and sold profitably in global markets. Firm collaboration and sources of information are important indicators for open innovation, and are discussed in the next two sections of this report.

Firm Collaboration

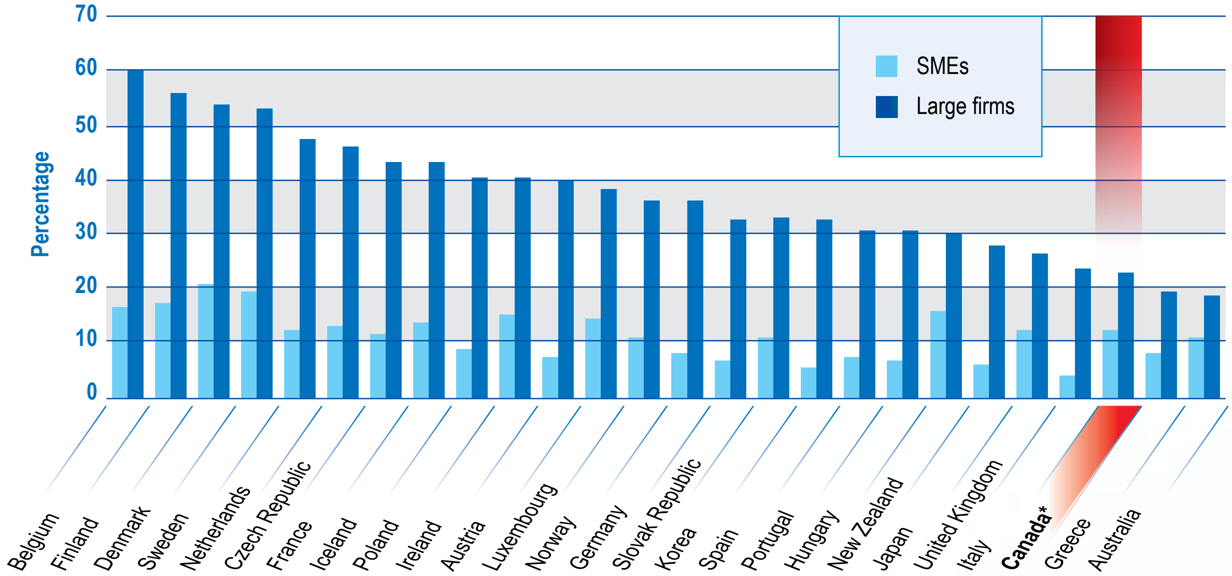
The straight line from a private firm's lab to new products and services has been replaced by a much more iterative, holistic process. Ideas are put out in the marketplace (*beta*), refined, put out again, and the whole process has many more feedback loops, each of which happens more quickly than before. For some companies and sectors, *time to market* is measured in days and weeks, not years, and *first to market* represents a significant competitive advantage.

Contributions come from many more sources (new countries and new sources of knowledge). Ideas for new products, services, processes and business models come from users, suppliers, and other industries, anywhere in the world. In addition, new Internet applications (*Web 2.0, Web 3.0*) have allowed firms to perform corporate functions (e.g. marketing, finance, design, R&D) anywhere in the world. This has led to a huge rise in firms that specialize in these corporate functions. Functions and services that used to take place within integrated manufacturing firms now increasingly take place outside those firms.

[50] P. Therrien and P. Hanel, *Innovation and Establishments' Productivity in Canada: Results from the 2005 Survey of Innovation* (2009, forthcoming).

Finally, challenges and opportunities at the company level increasingly demand investments and skills beyond the capacity of individual companies and organizations. All of these events have led to a rise in the importance of collaboration between firms engaging in innovative activities. The measure we have chosen — firms collaborating in innovative activities, by size — measures the joint development of new products, services, and processes, as well as horizontal work with other firms or public research institutions. It excludes the pure *contracting-out* of work.

Figure 11: Firms Collaborating in Innovative Activities with Public and/or Private Partners by Size, 2001–04



* Manufacturing sector only.
Source: OECD STI Scoreboard, 2007.

As Figure 11 shows, over the period 2001–04, Canada ranked only 24th in the OECD in the percentage of firms collaborating in innovative activities, our worst performance in the *Business Innovation* basket of indicators. This indicates that Canadian firms in the manufacturing sector are relatively insular islands of entrepreneurial activity. In a world where collaboration on innovative activities is increasingly essential to performance and meeting market needs, our performance on this indicator is indeed troubling.

User-Initiated Innovation Leads to Medical R&D Company

In 1999, Lee Valley Tools CEO, Leonard Lee, received a thank you letter from Dr. Michael Bell, a renowned Ottawa professor and plastic surgeon, for inadvertently helping to create the world's best scalpel. A pioneer in microvascular surgery, Dr. Bell had used a Lee Valley wood carving knife he had purchased from Lee Valley Tools as a scalpel. The handle was rounder and easier to grip than a standard flat handled scalpel, and also boasted an easy release mechanism for the blade. When Lee visited Dr. Bell, Lee found that he used no less than 17 different Lee Valley Tools in his clinic. Before long, Lee launched Canica Design Inc., which has grown from a surgical instrument company to one that develops a complete range of wound stabilization and closure devices. These devices significantly reduce disfigurement, scarring, pain and the need for skin grafts and mesh repair.

Clusters

While there is debate on the precise scope of the definition, a cluster is generally considered to consist of a geographical region in which there is a high concentration of firms in a given sector. These firms may be in the same industry and may have similar characteristics and products to each other, or may occupy complementary positions in a value chain and be each other's suppliers and customers. Industrial clusters are not necessarily in high-tech fields, and are not necessarily innovation driven. However, the dynamics of clusters are particularly important to high-tech industries and highly innovative sectors.

Geographical co-location provides a variety of competitive advantages to firms. Physical proximity facilitates linkages between firms, and can reduce the costs of innovation through shared resources and information.[51] The availability of resources or endowments not available elsewhere can also contribute to co-location.[52] For knowledge-based industries, the availability of a large labour pool of highly qualified or specialized people is a benefit, as employment turnover in firms can provide the talent required for growth by other firms. Clusters also become centres of specialized investment capital. Local investment firms can become adept at evaluating and supporting entrepreneurs in specific sectors or industries; and a concentration of firms of a certain industry can attract investment firms that specialize in that industry. The availability of specialized capital and the concentration of talented individuals provide the environment for the formation of new businesses, and many clusters are characterized by high rates of start-ups and high levels of entrepreneurship.

Clusters emerge as a result of market forces, but their growth can be assisted by policy. Foundational policies may be the most important — for example, the high rate of employee mobility in Silicon Valley, which contributed to the emergence of the tech cluster, has been attributed partly to the characteristics of California's labour laws governing non-compete agreements in contracts.[53] Specific policies to encourage the formation of clusters may also help cluster growth. For example, policies that encourage collaboration between various institutions in key sectors may prove beneficial, as can cooperation between different levels of government to focus public R&D into areas of existing local economic strength.[54] The provision of knowledge 'infrastructure,' such as research institutions, incubators and agents to broker collaboration between firms can also play a helpful role.[55]

A Centre of Canadian Research Excellence: Montréal's Biotech/Pharmaceutical Cluster

Montréal is home to hundreds of research-based pharmaceutical companies, anchored by the research labs and head offices of a number of large multinational pharmaceutical companies such as Pfizer. The cluster is also supported by the presence of two research universities with strong health sciences faculties: the University of Montréal, and McGill University, which was rated one of the world's top 10 life sciences universities by the Times Higher Education Supplement university rankings. These universities generate numerous spinoff companies, and supply graduates to local businesses. Montréal is also home to the National Research Council's Biotechnology Research Institute, a government lab that undertakes strategic research in the area of health sciences, and actively engages with local university and business partners on R&D projects, helping to foster and strengthen networks of key players. Montréal's high profile, strong intellectual property protection, good research infrastructure and a favourable R&D tax regime make it an attractive location for pharmaceutical venture capital companies. The presence of multinationals (many of which have investment branches) further enhances the availability of start-up and expansion capital for entrepreneurs.

[51] OECD, "Boosting Innovation: The Cluster Approach," OECD, 1999, p. 7.

[52] OECD, "Boosting Innovation: The Cluster Approach," OECD, 1999, p. 179.

[53] B. Fallick, C. Fleischman, and J. Rebitzer, *Job Hopping in Silicon Valley, The Review of Economics and Statistics*, Vol. 88, No. 3, August 2006, pp. 472–481.

[54] OECD, *Innovative Clusters: Drivers of National Innovation Systems*, 2001, p. 38.

[55] OECD, *Boosting Innovation: The Cluster Approach*, OECD, 1999, p. 179.

Sources of Information for Innovative Manufacturing Firms

A study examining the sources of information for innovative Canadian manufacturing firms from publicly funded research organizations found that universities and federal and provincial labs were significantly less likely to be identified as an important source of information by innovative firms. Rather, the top three sources identified were clients or customers; suppliers; and conferences, trade fairs and exhibitions.[56]

Moreover, the study found that innovative firms were significantly more likely to collaborate with other firms than with publicly funded research organizations. This can be largely explained by the frequency of interactions between an innovator and its suppliers and clients. In general, innovators are in constant contact with these two groups in the production and marketing of their activities and products.

Other countries make far more use of their public institutions (higher education and government) than Canada does. As Figures 12 and 13 show, Canada is almost at the very bottom of the pack when it comes to companies interacting with public research organizations. The U.S. is not included as it has not conducted comparable innovation surveys.

Figure 12: Firms Collaborating on Innovation with Higher Education Institutions, by Size,[1] 2002–04[2]

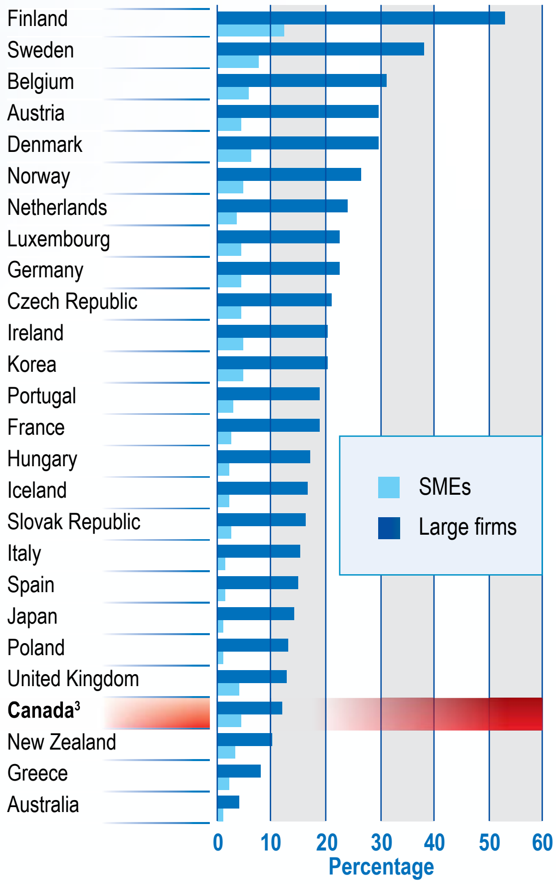
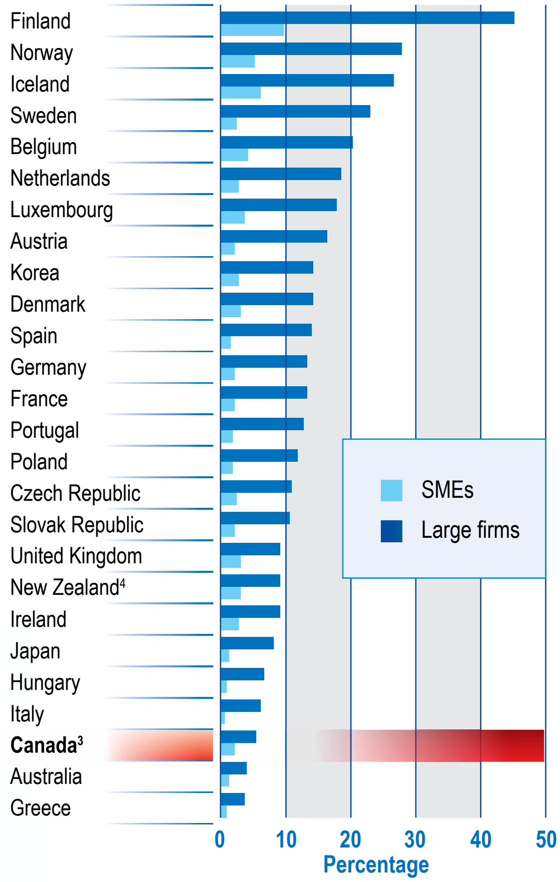


Figure 13: Firms Collaborating on Innovation with Government, by Size,[1] 2002–04[2]



1 SMEs: 10–249 employees for European countries, Australia and Japan (persons employed); 10–99 for New Zealand, 10–299 for Korea, 20–249 for Canada.

2 Or nearest available years.

3 Manufacturing sector only.

4 Refers to firms that cooperate with Crown Research Institutes, other research institutes or research institutions.

Source: OECD Science, Technology and Industry Scoreboard, 2007.

56 Anderson, Frances. *The Transmission of Technology and Knowledge to Innovative Canadian Manufacturing Firms by Publicly Funded Research Organizations*, Policy Research Initiative Working Paper Series 036, May 2008.

4.2 Canada's Knowledge Development and Transfer Indicators

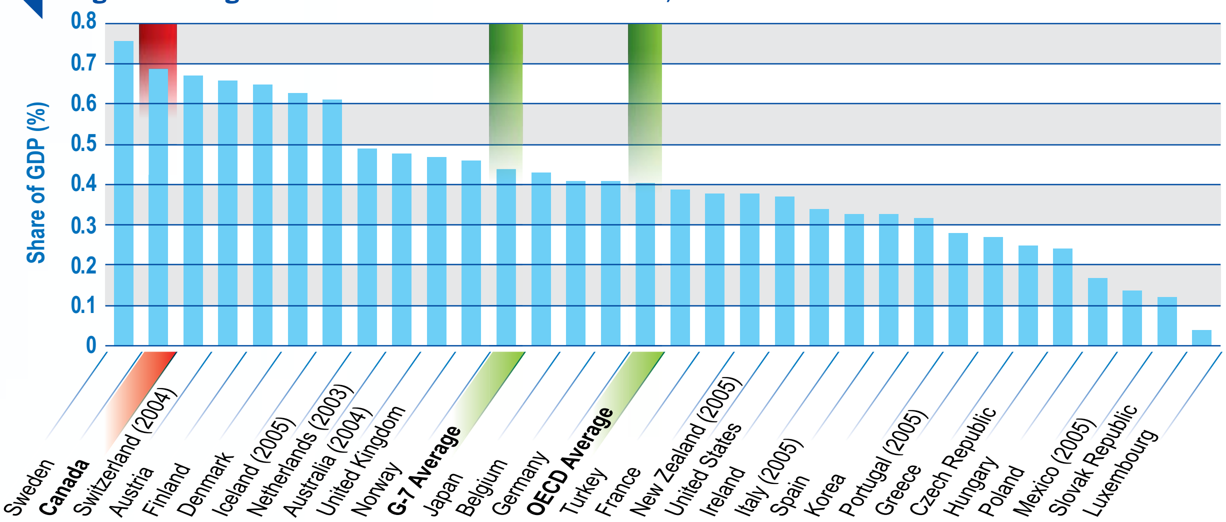
Scientific progress — from the emergence of agriculture, to the mapping of the human genome — marks human progress. As researchers learn more about the world, the pool of knowledge that is formally and informally shared expands. One researcher's discovery gives another a new idea on which to build. While the *outputs* of scientific research are notoriously difficult to quantify, it seems that innovative, successful and dynamic knowledge-based economies have at their core a complex web of interactions between industry, the local scientific community and the international scientific establishment. Canadian research benefits the Canadian economy by providing the foundation for future innovations, while at the same time contributing to the global state of science.

Basic, fundamental scientific research takes place mainly in universities. The role of universities is also evolving and many conduct later-stage applied and more immediately commercial relevant research. New economic research is also highlighting the important role of universities as *knowledge hubs* that act as points of informal research coordination between business, government and universities and between individual firms. University professors are often linked in to global networks of other research professionals. Internationally networked universities can act as conduits for the world's knowledge into the national economy.

Perimeter Institute: Space, Time, Matter and Information

Perimeter Institute for Theoretical Physics (PI) in Waterloo, Ontario is an independent, non-profit, scientific research and educational outreach organization where international scientists cluster to push the limits of our understanding of physical laws and develop new ideas about the very essence of space, time, matter and information. PI has attracted some of the best and brightest minds in the field of theoretical physics, including Stephen Hawking, just one of many international Distinguished Research Chairs. PI was founded in 1999 when Mike Lazaridis, founder and Co-CEO of Research In Motion (RIM) — maker of the successful BlackBerry™ — helped to foster research and innovation in Canada by donating $100 million of his own money to establish the institute. He has since contributed an additional $50 million. Over this time, all levels of government combined to provide an equivalent amount. In partnership with the governments of Ontario and Canada, the Perimeter Institute continues to be a successful example of private and public collaboration in science research and education.

Figure 14: Higher Education Performance of R&D, 2006



Source: OECD Main Science and Technology Indicators, 2008.

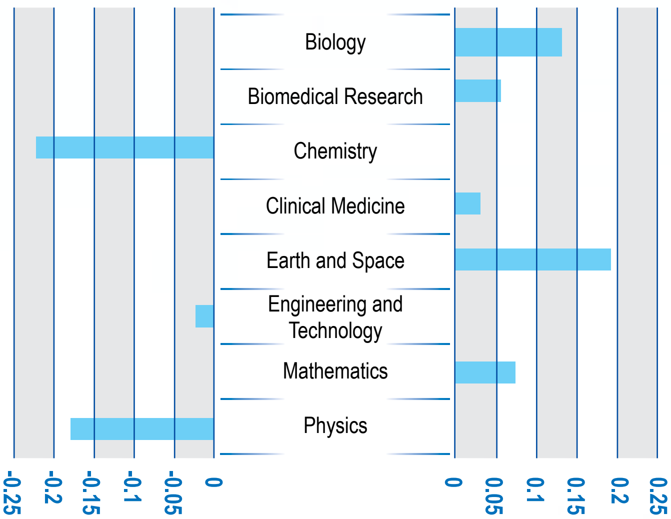
In Canada, the share of total national R&D that is performed by universities is among the highest in the OECD and is well above G-7 averages. Around one third of all R&D in Canada in 2006 was performed by universities. Canadian university R&D performance is also quite high relative to the size of the Canadian economy. As Figure 14 shows, in 2006, Canadian university R&D as a share of GDP was second only to Sweden in the OECD, and was significantly above G-7 and OECD averages.[57] Canadian public policy has made universities major performers of R&D and hubs of broader research networks. It should be noted that there are methodological differences in how the U.S. compiles higher education research and development data, which makes comparisons between the U.S. and other countries problematic.[58]

The results of scientific research, especially the basic-level scientific research usually carried out by universities, are often made public through papers published in peer-reviewed journals. Journal publications can be used as an indicator of a country's performance of new research at earlier pre-commercial stages. The rate of Canadian publication per researcher (including both social sciences and natural sciences and engineering) is on par with the G-7 average. Internationally comparable data are fairly sparse on university researchers in natural sciences and engineering, but from the available data, it seems Canadian researchers in these fields are relatively prolific publishers. Publications per Canadian natural sciences and engineering researcher are near the top of the pack of those countries for which data are available.[59]

Publications data can also be used to get a rough idea of the scientific specialization of a country.[60] This is done by comparing the share of publications in a field produced by a given country to the share of publications in that field in a larger sample of countries. While research in some fields is more prone to publication than research in other areas, the ratio of a country's publication in a given field to this ratio for other countries gives an indicator of where a country's scientific research is concentrated.

Figure 15 shows that there is a strong relative concentration of published Canadian research in the biology and the earth and space fields. Each of these fields contains sub-fields. For example: agriculture and food science, dairy and animal science, and ecology are all sub-fields included in the biology field. The earth and space field includes the sub-fields geology and environmental science. These specializations could be seen to be a reflection of the economic importance of Canada's agricultural and resource sectors, and perhaps of a Canadian specialization in environmental and ecological S&T. Such specialization may suggest areas of basic research strength upon which Canadian innovation can build. It should also be noted that only the broader categories of scientific publications are captured in these data. Within these categories there are numerous Canadian specializations at the sub-field level. For example, while Canada has a negative relative specialization in the engineering and technology field, Canada actually has a strong specialization in the sub-field of civil engineering.

Figure 15: Canadian Specialization by Publication Field*



* Revealed Symmetrical Scientific Advantage (RSSA) relative to World. The RSSA is a measure of the concentration of a country's overall publications in a given field, relative to the overall concentration of publications in this field in the world (or comparitor countries). For more information on the calculation of the RSSA, please see the work referenced in footnote no. 60.

Source: OST.

57 OECD, *Main Science and Technology Indicators*, 2008/1.

58 Association of Universities and Colleges of Canada (AUCC), *Trends in Higher Education*, Vol. 3, *Finance*, p. 46.

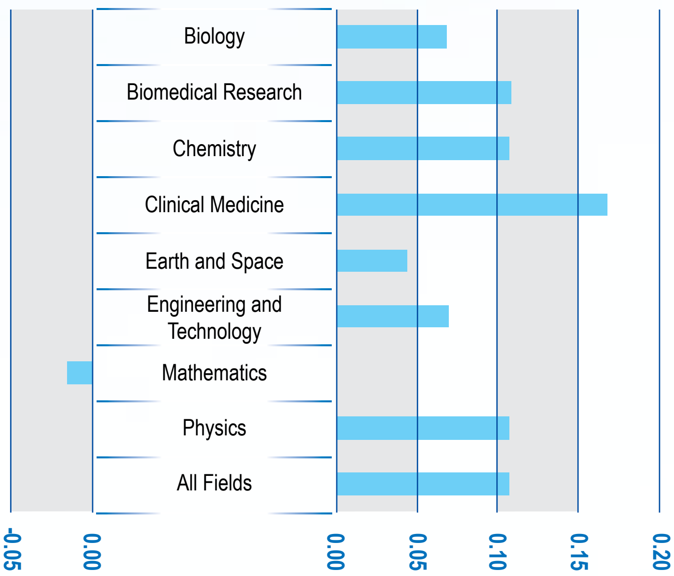
59 Observatoire des sciences et technologies, *Publications 2008*, 2008/9; OECD, *R&D Personnel by Sector of Employment and Occupation*, OECD.stat, downloaded October 2008.

60 M. Cincera*, Brain Drain, Brain Gain and Brain Exchange: The Role of MNEs in a Small Open Economy. Beyond Borders: Internationalisation of R&D and Policy Implications for Small Open Economies*. A. Stiphoven, and P. Teirlinck (eds.), Brussels: Elsevier / Belgian Federal Science Policy. 2005. 179–206.

Metrics based on the number of publications (such as average publications per researcher and revealed scientific advantage), however, only give part of the story. While the peer-review process generally keeps unsubstantiated or trivial research from being published, there are nonetheless considerable variations in the quality of research that is published. To get an approximate measure of the quality of the scientific papers being produced, researchers often look at the number of times a given scientific paper is cited as a source. Like any measure this indicator is not perfect, but the times a paper is cited as a source of ideas in the research that follows, can be an indication of the degree of its impact on scientific advancement.

The Observatoire des sciences et technologies organization in Quebec produces an Average Relative Impact Factor (ARIF) metric, which measures the national rate of publication in highly cited journals relative to the average world rate of publication in these journals, by field.[61] By this measure, Canadian research is of a very good quality, with an ARIF measure that is sixth among OECD countries. Figure 16 shows that for 2006, the fields in which Canadian research papers had the greatest impact (compared to the average of OECD countries) were clinical medicine, chemistry, biomedical research and physics, suggesting strong Canadian scientific competencies in these areas.

Figure 16: Average Relative Impact Factor by Field: Canadian Impact Relative to Average of OECD Countries



The Average Relative Impact Factor is a proxied measure of the number of citations per article published by researchers in a given country and field of research, relative to the proxied average number of citations for all articles in that field. The ARIF here is measured relative to world publications, and the difference between the Canadian ARIF and the ARIF for the average of OECD countries is represented in the chart above. Refer to the Observatoire des sciences et technologies for more information on the calculation of the ARIF.

Source: OST.

In recent years, the science communities in a number of industrializing countries have begun to make an impact. The rise of these nations is now being reflected in publications data. China and South Korea are now making significant contributions to the global total of published scientific literature. India's publications (always quite high for a developing country) have also grown quite quickly since the early 1990s. Growth in the number of scientific publications coming from Turkey, Taiwan, Portugal, Brazil, Mexico and Poland, to name a few, has also been quite strong. The emergence of these countries is far from a threat for Canadian science — rather, it is an opportunity. If Canadian researchers are well connected to these emerging sources of new knowledge, then Canadian researchers can build on this knowledge and further the possibilities for Canadian innovations. For this reason, it is important that Canadian research institutions and researchers network globally and not just regionally, to keep abreast of the latest scientific discoveries wherever they may occur.

Indicators that consider not just quantitative, but also qualitative and less tangible variables can be useful for evaluating the international standing of Canada's universities. Reputation matters, and having internationally recognized, first-rate research universities helps a country recruit and retain the best scientific researchers. A good reputation may also contribute to a university's ability to network, may improve opportunities for collaboration, and may attract research funding and funding for scholarships. If more Canadian universities were internationally recognized that would help cement the international reputation of our higher education sector. There are two commonly cited sources for measuring the quality of universities: the Graduate School of Education, Shanghai Jiao Tong University (GSE-SJTU) Academic Ranking of World Universities; and the Times Higher Education Supplement — Quacquarelli Symonds (THE-QS).

61 Observatoire des sciences et technologies, *Publications 2008*, 2008/9. http://www.ost.uqam.ca/Accueil/tabid/36/Default.aspx.

The GSE-SJTU Academic Ranking of World Universities evaluates universities on four criteria: quality of education, quality of faculty, research output and size of institution. These are all based on measured data such as awards per faculty member and citations. In 2008, according to GSE-SJTU, Canada had four universities in the top 100: University of Toronto (24th place), University of British Columbia (35th place), McGill University (60th place) and McMaster University (89th place).[62]

The THE-QS includes both quantitative measures (such as citations per faculty member) and qualitative (such as the opinion of surveyed academics) in its rankings. In the top 100 universities for 2008, the THE-QS included five Canadian universities: McGill University (20th place), University of British Columbia (34th place), University of Toronto (41st place), University of Alberta (74th place) and University of Montréal (91st place).[63]

> In the field of technology, Canada has eight universities in the top 100 [...]

The THE-QS, as well as producing overall rankings, produces rankings of universities in various categories. On individual categories, Canadian universities seem to fare better. In the field of natural sciences, Canada has seven universities in the top 100 (University of Toronto, 9th; University of British Columbia, 20th; McGill University, 22nd; University of Waterloo, 42nd; University of Alberta, 51st; McMaster University, 82nd; and Université de Montréal, 91st). In the field of technology, Canada has eight universities in the top 100 (University of Toronto, 10th; McGill University, 18th; University of British Columbia, 22nd; University of Waterloo, 30th; University of Alberta, 46th; McMaster University, 79th; Université de Montréal, 87th; and University of Calgary, 90th). In the field of life sciences and biomedicine, Canada has seven in the top 100 (McGill University, 10th; University of Toronto, 13th; University of British Columbia, 14th; University of Alberta, 45th; McMaster University, 52nd; Université de Montréal, 60th; and Dalhousie University, 90th).

There are a number of differences between the methodologies and data sources used in these two surveys, which account for the differences in how universities are ranked.[64] For example, the THE-QS is based on prorated data, most often adjusted to consider the size of the institution being ranked. In many of the GSE-SJTU Academic Ranking of World Universities survey's categories, only gross numbers count — there is no accounting for size. Additionally, the GSE-SJTU ranking awards 40 percent of the indexed value to research, compared with 20 percent in the THE-QS. The GSE-SJTU ranking also awards 40 percent to faculty members having won Fields Medals and Nobel Prizes.[65]

[62] Graduate School of Education (formerly the Institute of Higher Education), Shanghai Jiao Tong University, *Academic Ranking of World Universities — 2008*, August 2008. Accessed at http://www.arwu.org.

[63] Times Higher Education Supplement, *World University Rankings 2008*, 2008/10. http://www.timeshighereducation.co.uk/hybrid.asp?typeCode=243&pubCode=1.

[64] The Shanghai ranks universities by several indicators of academic or research performance, including total number of alumni and staff winning Nobel Prizes and Fields Medals, total number of highly cited researchers, total number of articles published in *Nature* and *Science* over the past five years, total articles indexed in major citation indices in the past year, and the per capita academic performance of an institution. For each indicator, the highest scoring institution is assigned a score of 100, and other institutions are calculated as a percentage of the top score. The distribution of data for each indicator is examined for any significant distorting effect; standard statistical techniques are used to adjust the indicator if necessary. The initial objective of the THE-QS World University Ranking was to develop a holistic evaluation of universities that enabled comparison of institutions across borders. In order to achieve this, four principal criteria were identified (Research Quality, Graduate Employability, International Outlook, and Teaching Quality). The indicators used to assess these criteria are academic peer review (weighted by region), recruiter review (weighted by region), student–faculty ratio, citations per faculty member over past 5 years (scaled according to institution size), proportion of international faculty, and proportion of international students. For each indicator, the highest scoring institution is assigned a score of 100, and other institutions are calculated as a percentage of the top score. The distribution of data for each indicator is examined for any significant distorting effect; standard statistical techniques are used to adjust the indicator if necessary. Scores for each indicator are weighted to arrive at a final overall score for an institution. The highest scoring institution is assigned a score of 100, and other institutions are calculated as a percentage of the top score.

[65] OECD; *Breaking Ranks, OECD Observer*, No. 269, October 2008. http://www.oecdobserver.org/news/printpage.php/aid/2768/Breaking_ranks.html.

While these rankings provide some insight into how Canadian universities are perceived internationally, and how individual Canadian universities perform on certain measures, the usefulness of these indices for broad international comparison is nonetheless limited. Germany, for example, has six universities in the Academic Ranking of World Universities top 100, whereas Canada has four. Canada's top university rates higher than Germany's top university. Based on this, which country has a *better* system of universities? Finland, by contrast, has only one university in the top 100 rankings. But, since Canada's population is around six times larger than Finland's population, should this be interpreted that Finland's university system outperforms Canada's university system? Furthermore, as the OECD has recently pointed out, these indicators do not measure some other important aspects of university quality; for example, the quality of the teaching curricula or coursework.[66]

The World Economic Forum's survey of executives places the quality of Canadian scientific research institutions (including universities and government research labs) quite high. In the 2008–09 survey, these institutions were ranked fourth in the world, and ahead of every G-7 country but the U.S.[67]

While the overall picture is mixed, the balance of evidence suggests that many Canadian universities are first-rate scientific institutions. But in the context of the knowledge-based economy, it is not considered sufficient for a country's universities to produce groundbreaking scientific research in isolation. A growing body of research suggests that effective links between the three principal innovation funding/performing sectors are an important contributor to a successful national innovation system, especially as a mechanism for transfer of S&T into the commercial sphere.[68, 69] When it comes to the networking of Canada's universities with other sectors of the Canadian economy, the picture of Canada's performance is somewhat ambiguous.

University of British Columbia and MIV Therapeutics: Cross-Border Teamwork to Fight Heart Disease

Many Canadian universities are establishing and solidifying their links to industry and cementing their role as networked research hubs and as 'entrepreneurial universities.' Just as these institutions are developing strong local and national networks, Canadian universities are also becoming internationally networked centres for education and research, and are harnessing cross-border collaboration to solve the scientific and technological problems of the day.

Joint research, supported by the Natural Sciences and Engineering Research Council of Canada, the University of British Columbia (UBC) and Georgia-based MIV Therapeutics, led to the development of a new technology which allows doctors to surgically implant tiny devices to hold clogged arteries open, without triggering the body's natural immune system rejection of these devices. In 2008, MIV Therapeutics and researchers from UBC won the Frost & Sullivan North American Technology Innovation award in the field of interventional cardiology for this pioneering work.

[66] OECD; *Breaking Ranks, OECD Observer*, No. 269, October 2008. http://www.oecdobserver.org/news/printpage.php/aid/2768/Breaking_ranks.html.

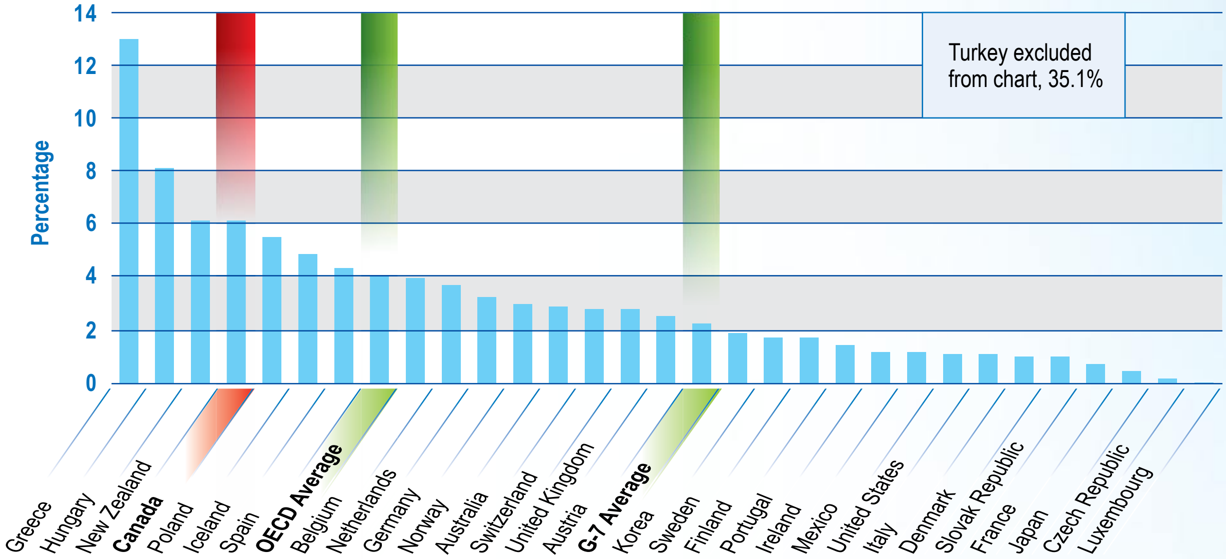
[67] World Economic Forum, *Global Competitiveness Report 2008–2009*, http://www.weforum.org/documents/gcr0809/index.html.

[68] P. Shapira and J. Youtie, *Building an innovation hub: A case study of the transformation of university roles in regional technological and economic development, Research Policy*, Vol. 37, Issue 8 (2008), pp. 1188–1204.

[69] A. Bramwell and D. Wolfe, *Universities and Regional Economic Development: The Entrepreneurial University of Waterloo*, Research Policy, 37, 2008, 1175–1187.

The funding of higher education R&D by business (see Figure 17) has been used as a proxy for business–university R&D linkages.[70] The share of Canadian university R&D that is financed by business is one of the highest shares in the world. R&D performed by Canadian universities, which is financed by business as a share of total business-financed R&D, is also quite high, relative to other OECD countries.[71]

Figure 17: Share of All Business-Financed R&D that is Performed by the Higher Education Sector, avg. 2003–06



Source: OECD.stat database, Gross Domestic Expenditure on R&D by Sector of Performance and Source of Funds. 2008/10.

The precise reasons underlying the relatively high level of this type of R&D cross-funding in Canada are not clear, as internationally comparable qualitative information on business funding of university R&D is scarce.[72] Within Canada, however, there is some evidence about several factors that lead to business R&D collaboration with universities. The use of universities as research partners varies considerably by industry and by firm type in Canada. Companies in the pharmaceutical and medicine manufacturing industry, for example, are more likely to report universities as an important source of knowledge than are companies in the plastics and rubber products manufacturing industry. Some Canadian researchers suggest that the firms most likely to partner with universities are also more likely to be larger firms, more dependent on technological innovation for their competitiveness.[73] Other research notes that "…few firms have the necessary resources — be it knowledge, skills or costly equipment — to be self-sufficient in attaining their innovation goals…" suggesting cost savings as an important motivation for business–university R&D collaboration.[74] For others, while cost is certainly an incentive to collaboration with universities, "the major incentive… is the access to research and critical competencies."[75]

70 J. Rosa and P. Mohnen, *Knowledge Transfers between Canadian Business Enterprises and Universities: Does Distance Matter?*, CIRANO - Scientific Publication No. 2008s-09, March 2008.

71 OECD, *Main Science and Technology Indicators*, 2008/1; OECD, *Gross Domestic Expenditure on R&D by Sector of Performance and Source of Funds*, OECD.stat, downloaded October 2008.

72 One suggested reason for the high level of private funding of university R&D in Canada may be extensive use of university research staff as consultants to Canadian industry, though the evidence is not conclusive. Cooper, D., *The Facts on University Spin Offs*. Presentation to Alliance for Commercialization of Canadian Technology, November 8, 2005.

73 P. Hanel and M. St-Pierre, *Industry–University Collaboration by Canadian Manufacturing Firms*, Journal of Technology Transfer, Vol. 31, No. 4 (July 2006), pp. 485–499.

74 HAL Technology Management, Strategy and Economics. *Review of Programs Supporting Collaborations between Higher Education and Industry*. Prepared for Higher Education R&D Policy Directorate, Industry Canada, 2008.

75 P. Hanel and M. St-Pierre, *Industry–University Collaboration by Canadian Manufacturing Firms*, Journal of Technology Transfer, Vol. 31, No. 4 (July 2006), p. 496.

The Conference Board of Canada notes that firms collaborate with universities and public research institutions for a number of reasons, including: the credibility of the collaborating partners (which is a valuable marketing asset); the opportunity to interface with globally networked researchers; improving the knowledge and abilities of their internal research staff through the cooperative endeavour; access to specialized university talent; and the opportunity to identify and hire promising research students.[76] In addition to these perceived benefits of collaboration with universities, there is some evidence that firms collaborating with universities tend to produce innovations that are more original than non-collaborating firms.[77] If Canadian universities and businesses do engage in a high rate of collaboration, then this should be a source of competitive advantage for Canada.

However, the picture here is mixed. While businesses spent a relatively high proportion of their R&D dollars in universities, the OECD placed Canada near the bottom of OECD countries in terms of the proportion of businesses collaborating with universities for R&D.[78] In the World Economic Forum's survey of executives, a relatively low share of Canadian executives gave positive reviews of the state of university–business cooperation in Canada.[79] These different findings suggest that a more in-depth look is needed, not only at the numbers of companies collaborating with universities, but also looking at companies' own perceptions of that collaboration. Collaboration between universities and firms on research projects is one way for the knowledge produced and embodied in universities to be transferred into the commercial business sphere, but it is not the only channel. Businesses may also purchase the licence to use intellectual property generated through university research. Another major channel of commercialization is the generation of small, research-intensive spinoff companies from university research.

Technology licences are a useful means of knowledge transfer between public research institutions and the private sector. The number of technology licences also helps measure the match between research conducted by research organizations/institutions and the needs of industry. Compared to the U.S., Canada's licensing income per dollar of sponsored research has seemingly remained low over the past ten years. While the U.S. economy is roughly ten times as large as Canada's, its total licensing income is more than 30 times greater.[80]

University spinoffs are small companies that are based on university research and usually headed, at least initially, by the university researchers responsible for a discovery. These spinoff companies are vehicles for the commercialization of university research. Simply put, they are a means through which the scientific research undertaken by universities directly enters the private sector. This research is then turned into marketable products and services, creating tangible economic value for an economy.

In 2003, the last year for which Statistics Canada data are available, 1350 university spinoffs were active in Canada.[81] A 2005 analysis of Canadian spinoff performance indicated that, relative to the size of the economy, Canada had one of the world's highest levels of spinoff firms.[82] Other research by Canada's Industrial Research Assistance Program has suggested that university spinoffs are likely to retain strong and productive R&D partnerships with universities as they grow.[83]

In 2003 [...] Canada had one of the world's highest levels of spinoff firms.

76 Conference Board of Canada, *Annual Innovation Report 2006; Lessons in Public–Private Research Collaboration: Improving Interactions Between Individuals* (2006).

77 P. Hanel and M. St-Pierre, *Industry–University Collaboration by Canadian Manufacturing Firms*, Journal of Technology Transfer, Vol. 31, No. 4 (July 2006).

78 OECD, *Science, Technology and Industry Scoreboard, 2007* (2007).

79 World Economic Forum, *Global Competitiveness Report 2008–2009 (2008) accessed at,* http://www.weforum.org/documents/gcr0809/index.html.

80 Association of University Technology Managers, *AUTM Canadian Licensing Activity Survey, FY 2006*. 2007; Association of University Technology Managers, *AUTM US Licensing Activity Survey, FY 2006* (2007).

81 M. Bordt and L. Earl, *Public Sector Technology Transfer in Canada, 2003*. Statistics Canada, Catalogue No. 88F0006XIE — No. 018 (November 2004).

82 Cooper, D. *University Spin Off Firms and High Growth Firms in Canada*. APEC Newsletter, 3, June 2007.

83 NSERC. *Research Means Business: A directory of companies built on NSERC-supported university research*. NSERC, 2005. References an IRAP study, no citation.

DALSA Corporation: Canadian Technology on Mars

DALSA Corporation was 'spun off' in 1980 as a consulting company with a specialization in the emerging field of photoelectric semiconductors. The initial research was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC), and the early support for the spinoff company came from business development services at its parent university, from the Government of Ontario and from private venture capital sources. The fundamental, NSERC-funded research was the basis of further R&D collaborations with the National Research Council Canada and other federal government agencies. The expertise of DALSA's researchers gained international recognition, and as DALSA provided research services on image sensor projects to various national and international companies, DALSA's reputation continued to grow, as did the company itself. In 2004, image sensor chips aboard the Mars Twin Rover, 'Spirit' and 'Opportunity,' and manufactured in DALSA's Bromont facilities, beamed back to earth the highest resolution colour images ever taken of another planet.

The annual Association of University Technology Managers survey of technology transfer for 2006 suggested that the rate of formation of university spinoffs in Canada has been in overall decline in recent years.[84] If, as some Canadian research suggests, spinoffs are an important channel for the commercialization of Canadian university research, then further research into the apparent decline in Canadian university spinoff activity may be warranted.

Across the OECD, businesses and other non-governmental agents are increasingly funding university research, but government remains the primary source of R&D funds for universities. In Canada, government funding for university R&D has had particularly strong growth, and has increased as a share of GDP every year since 1997 (though business funding of university R&D has grown even faster). Universities receive the majority of Government of Canada R&D funding that goes to outside entities.

As a share of GDP, Government of Canada funding of university R&D is higher than the G-7 average, which is consistent with the generally large contribution to national R&D made by Canadian universities. Government funding for higher education R&D in Canada (including both direct and indirect funding) took off starting around 1997–98. From having the second lowest 1989–1997 growth rate in the G-7, government funding of Canadian university R&D (as a share of GDP) grew at the fastest rate in the G-7 from 1997 to 2005. This rapid growth in government funding to universities is the principal reason why Canada's universities figure so prominently in today's national innovation system. Direct funding for universities has grown to become the most important component of Government of Canada R&D funding, and accounted for almost 50 percent of total federal R&D expenditures in 2007. This total does not include indirect government funding for university R&D through general university funds. If such indirect government funding is included, total government transfers of R&D funding to universities are even larger.[85]

Even before the SR&ED tax credits are considered, about one-third of Canadian R&D is either performed or funded by government sources.[86] This level is quite close to the G-7 average. Relative to the size of Canada's economy, however, the investment of the Canadian government in R&D, while close to the OECD average, is far lower than in the U.S., and is considerably behind the G-7 average. It also lags in the level of government investment in R&D of highly innovative countries like Sweden, Finland and South Korea.[87]

[84] Association of University Technology Managers, *AUTM Canadian Licensing Activity Survey, FY 2006* (2007).

[85] OECD, *Gross Domestic Expenditure on R&D by sector of performance and source of funds*, OECD.stat, 2008/10.

[86] This figure includes both federal and provincial government funding of government labs, government indirect funding of university R&D, government direct funding of university R&D, and government direct funding of business R&D.

[87] It should be noted that in the U.S., defence R&D spending accounts for a considerable share of government R&D funding (some 58 percent of total U.S. Government Budgetary Appropriations for R&D in 2006). OECD, *Gross Domestic Expenditure on R&D by sector of performance and source of funds*, OECD.stat, 2008/10; OECD, *Main Science and Technology Indicators*, 2008/1.

Hydrogen and Fuel Cells Technologies

The potential applications for hydrogen and fuel cells are countless — from running a wide variety of vehicles, to being used as sources of backup power, to powering cellular phones and laptops, to heating of hospitals and homes.

In 1997, fewer than 20 companies maintained hydrogen and fuel cell activities. Today, the Canadian hydrogen and fuel cell sector features over 100 stakeholders, including a number of core technology developers. Canadian capabilities in hydrogen and fuel cells extend across the country in Victoria, Vancouver, Calgary, Toronto and Montréal. Clusters of hydrogen and fuel cell companies, suppliers, infrastructure developers and service providers help accelerate commercialization by pooling talents and focusing efforts. Canadian hydrogen and fuel cell technologies are being sold today into product applications such as forklift trucks (U.S.), telecom backup power systems (U.S. and Germany), residential co-generation systems (Japan), and transit buses (Canada, U.S. and Europe).

Communications Research Centre Canada: An Internationally Networked Government Lab

The Communications Research Centre Canada (CRC) in Ottawa is the Government of Canada centre helping keep Canada at the forefront of communications technology. CRC supports government clients as they respond to priorities including national defence, public safety and space-based communications. CRC also provides advice for public policy purposes. Its contribution is felt nationally and internationally as its research informs the development of regulations and standards.

Helping to standardize the ATSC Digital Television System, which is replacing analog television, is a prime example of CRC's impact. Viewers in Canada will begin to enjoy a new era of digital television broadcasting as this country approaches the August 31, 2011 conversion deadline. Viewers in the U.S. will convert to digital in 2009. For its contribution to the development of the digital TV standard, CRC was recognized with an Emmy Award.

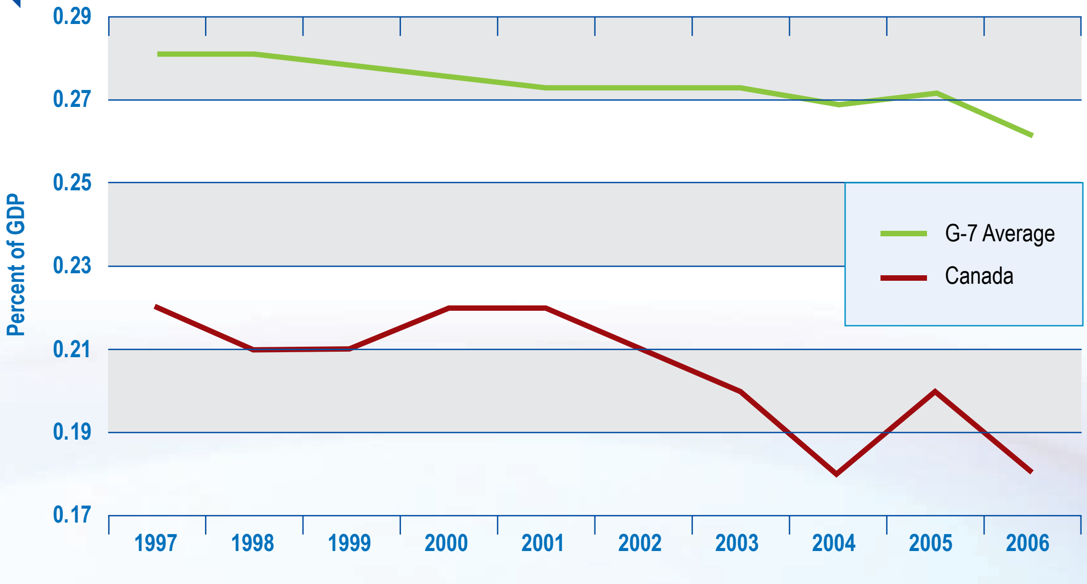
CRC collaborates with partners around the world. These collaborations have included working with India's Centre for Development of Telematics to construct a WiMAX-based cognitive radio system to bring wireless broadband to rural communities; and cooperating with the Republic of Korea's Electronics and Telecommunications Research Institute in the area of 3-D video.

CRC Emmy Award

As well as funding research in outside entities, governments also fund and operate a variety of research laboratories. In Canada, government labs perform research to ensure regulatory compliance, which ensures the health of Canadians and assures consumers of the safety and reliability of new products. Government research labs also undertake basic and applied research in a variety of strategic areas. While the principal financial contribution of government to research in Canada comes in the form of funding for R&D, which is carried out by universities (and, to a lesser extent, businesses),[88] in-house government research is an important feature of Canada's innovation landscape.

88 Statistics Canada, CANSIM table 358-0001, *Gross domestic expenditures on research and development, by science type and by funder and performer sector*. 2008/10.

Figure 18: Intramural Government R&D: Share of GDP in Canada and G-7



Source: OECD, Main Science and Technology Indicators, 2008/1.

Figure 18 shows that compared to the G-7 countries, Canada's government labs receive relatively less funding as a share of GDP, and over time the gap between Canada and the G-7 average has been growing. In 1990, R&D carried out in Canadian government labs, as a share of GDP, was some 14 percent lower than the G-7 average. By 2006, this gap had grown to some 31 percent.[89]

4.3 Canada's Talent Indicators

People play a critical role in a nation's innovation system because they are the creators and users of new knowledge. The process of innovation is becoming increasingly complex, with more players and requirements for collaboration. The spectrum of skills and competencies needed is higher, requiring advanced levels of education and wider experience. An innovating economy employs people who:

- have leading-edge research skills;
- have complex problem solving skills;
- are committed to lifelong training and updating of skills;
- know how to put new technology to work;
- exhibit leadership and entrepreneurship;
- bring products, processes and services to markets; and
- can engage and cooperate at an international level.

Aside from demanding innovative products, consumers are also innovators. The Internet has provided a powerful platform for users to channel their skills, experiences, and knowledge with each other and innovating companies.

Canada's workforce is among the best educated in the world and provides us with a competitive advantage on which we can build. A declining birth rate and aging population will translate into fewer people in the workforce. A critical concern is maintaining and increasing the number of highly educated people in the workforce. Workers whose skills are upgraded, new graduates and immigrants who bring international expertise and skills with them will all contribute to our pool of talent.

[89] OECD, *Gross Domestic Expenditure on R&D by sector of performance and source of funds*, OECD.stat, 2008/10.

Canada's 15-Year-Olds on Science, Math and Reading

The Programme for International Student Assessment (PISA) is a collaborative effort among OECD countries, and 57 countries participated in the 2006 assessment. PISA looks at the ability of 15-year-old students to apply knowledge and skills in key subject areas, and to analyze, reason and communicate effectively as they examine, interpret and solve problems. PISA is run once every three years, and in each year there is a special focus on one of the three subject areas — reading, mathematics and science. In 2006, science was the focus of the assessment, while reading and numeracy were also assessed. More specifically, students were tested on their ability to recognize scientific questions, use evidence, draw scientific conclusions and communicate these conclusions.

PISA results shown in Figure 19, illustrate that Canada's 15-year-olds score well compared to their international counterparts in science, ranking third with only Finland and Hong Kong-China scoring better. In mathematics, Canadian students continued to perform well but were outperformed by students in Chinese Taipei, Finland, Hong Kong-China, Korea, Netherlands and Switzerland. In reading, Canadian 15-year-old students maintained their fourth place ranking, the same level they achieved in PISA 2003; but were outperformed by Finland, Hong Kong and Korea.[90] This contrasts with previous assessments where Canada was only outperformed by one other country.

Figure 19: PISA: Estimated Average Score and Confidence Intervals for Selected Countries, Combined Science, All Students, 2006

Country	Mean Score	Standard Error	Compared to Canada
Finland	563	-2	+
Hong Kong (China)	542	-2.5	+
Canada	**534**	**-2**	**=**
Japan	531	-3.4	=
New Zealand	530	-2.7	=
Australia	527	-2.3	-
Netherlands	525	-2.7	-
Korea	522	-3.4	-
Germany	516	-3.8	-
United Kingdom	515	-2.3	-
Czech Republic	513	-3.5	-
Switzerland	512	-3.2	-
Austria	511	-3.9	-
Belgium	510	-2.5	-
Ireland	508	-3.2	-
Hungary	504	-2.7	-
Sweden	503	-2.4	-
OECD Average	**500**	**-0.5**	**-**
Poland	498	-2.3	-
Denmark	496	-3.1	-
France	495	-3.4	-
Iceland	491	-1.6	-
United States	489	-4.2	-
Slovak Republic	488	-2.6	-
Spain	488	-2.6	-
Norway	487	-3.1	-
Luxembourg	486	-1.1	-
Italy	475	-2	-
Portugal	474	-3	-
Greece	473	-3.2	-
Turkey	424	-3.8	-
Mexico	410	-2.7	-

Source: Statistics Canada, *Measuring Up: Canadian Results of the OECD PISA Study, The Performance of Canada's Youth in Science, Reading and Mathematics, 2006 First Results for Canadians Aged 15*, Cat. No. 81-590-XIE, 2007.

Continuing Education and Adult Knowledge and Skills

Technology often changes faster than school curriculum. Therefore, along with investing in new machinery and equipment, it is crucial that employers train their employees in how to use new technologies. The Conference Board of Canada found that Canada still performs relatively poorly in formal workplace training, investing considerably less than the U.S. and many European countries. Moreover, real per capita investment in training is actually falling. In 1996, the investment per employee was $842, while in 2006 it was only $699.[91]

The same report also finds that those with higher levels of education tend to participate in formal workplace training more than those without a secondary school diploma. This implies "that the Canadian workplace training tends to amplify differences in skills as opposed to compensating for these differences. Given the fact that skills atrophy over time, the lack of a solid lifelong learning approach to skills building may be exacerbating Canada's continuing adult literacy problem."[92]

90 Statistics Canada, *Measuring up: Canadian Results of the OECD PISA Study, The Performance of Canada's Youth in Science, Reading and Mathematics, 2006 First Results for Canadians Aged 15*, 81-590-XIE, 2007.

91 *How Canada Performs: A Report Card on Canada*, The Conference Board of Canada (June 2007).

92 *How Canada Performs: A Report Card on Canada*, The Conference Board of Canada (June 2007), p. 92.

Canadian Institutes of Health Research Synapse Program Inspires Next Generation of Health Researchers

The Canadian Institutes of Health Research is bridging the gap between health researchers and Canadian youth through its *Synapse* program. Between July 2007 and June 2008, *Synapse* mentors devoted over 13 000 hours of their time inspiring 55 000 Canadian students to be interested in science and health research.

Synapse mentors receive training in youth outreach and how to best communicate their passion for research to high school students. *Synapse* mentorship opportunities include summer science camps, virtual mentorship connections, science fairs, and lab-mentorship programs.

"I am thrilled to hear that students had a great time learning about my passion in life and at the same time enjoyed having their hands extract DNA from bananas," says Kusala M. Jayasuriya, a neuroscience graduate student at the Hotchkiss Brain Institute Health Research Centre who is studying molecular and genetic techniques. "I find this is a win-win situation. A mentor learns and benefits simply by being a mentor as much as the students learn and benefit from a mentor. I hope that I may inspire at least one budding mind to pursue a career in one of the most exciting fields in health research."

"The *Synapse* mentorship program gave me everything I had hoped for and more," says Samanta Krishnapillai, a grade 11 high school student at Middlefield Collegiate Institute in Markham, Ontario. "I also had the opportunity to network with many different people who worked with my mentor and I learned from their experiences as well."

Mentor Lisa Turchet helps students extract DNA at a CIHR *Synapse* workshop in Iqaluit, Nunavut.

The *International Adult Literacy and Skills Survey* tracks the knowledge and skills of 16–65 year old Canadians in prose and document literacy, numeracy and problem solving. More than 23 000 Canadians were tested in 2003. The survey found little improvement in the overall literacy of adult Canadians since they were assessed in 1994. Two in five adults scored below the desired thresholds for coping with skill demands of a knowledge society.[93]

Share of the Population with a Tertiary Education

For a nation to be able to incorporate productivity-enhancing innovations into its economy, it must have access to skilled people. An independent report commissioned by the U.K. government in 2006 stated, "Higher levels of skills drive innovation, facilitate investment and improve leadership and management. For innovation to be effectively implemented, businesses must be able to draw on a flexible, skilled workforce." [94] Just as universities produce the knowledge workers, which are crucial to innovation, colleges produce workers that have the skills and knowledge to flexibly adapt to today's fast-paced economic climate, implement the latest technologies in their workplace, and develop the kind of bottom-up innovation in their daily routines that drives productivity growth.

The share of the population with a tertiary education[95] is regarded as an indicator of a nation's supply of advanced skills. Almost all OECD countries have seen a rise in the education levels of their citizens over the past two decades. Canada has experienced the second largest increase in tertiary attainment, while Korea had the largest increase.

93 "International Adult Literacy and Skills Survey," *The Daily*, Statistics Canada, Wednesday, November 9, 2005.

94 *Prosperity for all in the global economy — world class skills*, Leitch Review of Skills, December 2006. p. 8. http://www.dcsf.gov.uk/furthereducation/uploads/documents/2006-12%20LeitchReview1.pdf.

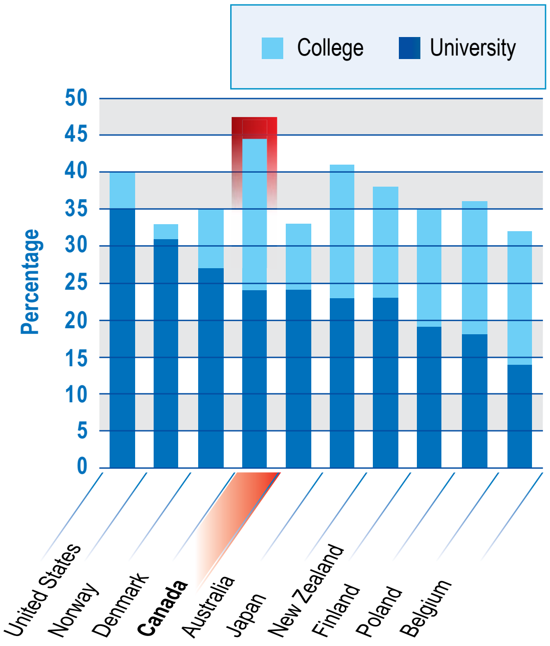
95 According to the OECD, university education is referred to as tertiary type-A education, including advanced research programs. College education is referred to as tertiary type-B. (OECD Education at a Glance; 2008.)

Figure 20 shows that among comparable countries, Canada ranks first in the educational attainment of its labour force. In 2006, 47 percent of Canada's working age population[96] attained a tertiary-level education, which is a significant rise from almost a decade ago when this percentage was 39 percent. Half of Canada's high percentage rests on the college component. This college to university ratio has remained relatively stable since 1999. In other leading OECD countries the college component is much smaller. Looking at just the university component of tertiary attaiment[97], Canada's rank falls to sixth place, behind the U.S., Norway, the Netherlands, Denmark and Iceland.

Countries define college and universities in different ways. In Canada, the college component includes trade and vocational programs.

Between 1998 and 2005, graduates from bachelor and master's programmes have been increasing,[98, 99] while the number of PhD degrees awarded has remained stable. When looking at fields of study at all levels of education, consecutive increases have been seen in business, management and public administration, representing 21 percent of all graduates in Canada. The social and behavioural sciences and law fields account for 20 percent, and humanities, 11 percent of all graduates.[100]

Figure 20: Percentage of Population with Tertiary Education, Top 10 OECD Countries (2006)



Source: OECD, Education at a Glance, 2008.

Canada, however, does not appear to reward this higher education, as the earnings advantage from completing tertiary education is low compared to other countries. Canada ranks the eighth lowest in the OECD in the earnings advantage of tertiary level graduates over persons with an upper secondary qualification.[101] Part of the explanation for this, and for the relatively high share of the Canadian college education, may be explained by the inclusion of short vocational programs in Canadian post-secondary education statistics that are reported by the OECD. The OECD is currently assessing differences in how member countries report this indicator.[102]

Nova Scotia Community College's Applied Geomatics Research Group sparks collaboration with local companies

The Applied Geomatics Research Group (AGRG) at the Nova Scotia Community College (NSCC) is one recipient of the Natural Sciences and Engineering Research Council's College and Community Innovation (CCI) Program. The Program received $48 million in Budget 2007 to increase innovation by boosting the capacity of Canadian colleges to work with local companies, especially small- and medium-sized enterprises. The AGRG is integrating geomatics and environmental technologies for landscape assessment, monitoring and restoration. The Group has been working with municipalities and the regional development agency to establish a Business Incubation Centre at its campus in the Annapolis Valley. Its business incubation process has involved five new companies since 2007.

96 Defined as ages 25 to 64 years old.

97 According to the OECD, university education is referred to as tertiary type-A education, including advanced research programs. College education is referred to as tertiary type-B. (OECD Education at a Glance; 2008.)

98 Statistics Canada, CANSIM table 477-0014, *University degrees, diplomas and certificates granted*.

99 *Momentum: the 2008 report on university research and knowledge mobilization*. Association of Universities and Colleges of Canada (2008).

100 Statistics Canada. *University degree, diplomas and certificates awarded, The Daily*, February 7, 2008.

101 OECD, Education at a Glance 2008: OECD Briefing Note for Canada (September 2008).

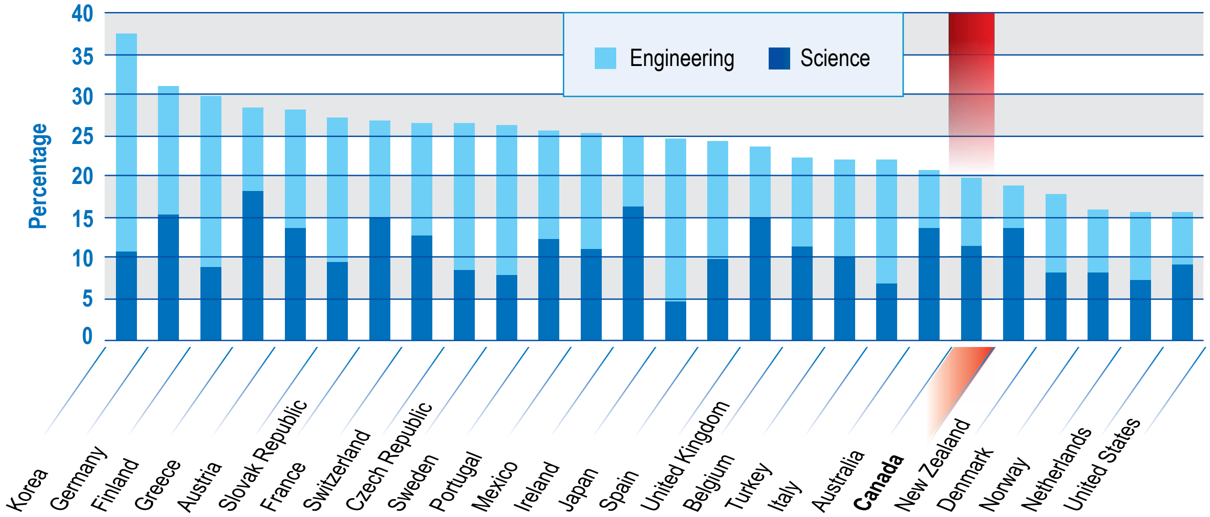
102 AUCC *Trends in Higher Education, Vol. 1, Enrolment, p. 22.*

Number of Science and Engineering Degrees

The long-term growth of Canada's innovation system requires constant growth in the number of workers possessing science and engineering (S&E) skills. Over the past 15 years, the vast majority of OECD countries have experienced a large increase in the number of students in S&T fields.[103] However, the proportion of S&T students as a percentage of all new degrees has steadily decreased during the same period in OECD countries.

In 2005, 20 percent of new degrees were awarded in S&E, which places Canada 21st among OECD countries (Figure 21). This percentage has remained somewhat stable since 1998. Despite this low ranking, however, Canada does perform better than its largest trading partner, the U.S., whose proportion is about 16 percent.

Figure 21: Science and Engineering Degrees as a Percentage of New Degrees, Selected OECD Countries (2005)



Source: OECD.stat, "Graduates by Field of Study."

To address the growing international demand and concern for scientific talent, an OECD working group examined the declining interest in S&T studies.[104] The OECD points out that students' choices are mostly determined by their image of S&T professions, the content of S&T curricula and the quality of teaching. Accurate knowledge about S&T professions and career prospects are key elements of orientation, but students lack complete information.

Booming Video Game Industry Benefits from University–Business Collaboration

In 2005 the University of Sherbrooke, the Cégep de Matane and international video gaming company Ubisoft announced the creation of the Ubisoft Campus in Montréal. This institution offers courses that lead to accredited degrees in fields related to video game development, and will teach students a complete range of skills needed by businesses in Montréal's booming game industry and abroad, including game design, modelling and 3-D animation. This innovative approach to university–business collaboration is just one of the ways in which Canadian institutions are collaborating with industry to provide their students with the skills that are in high demand.

[103] OECD Global Science Forum, *Evolution of Student Interest in Science and Technology Studies Policy Report*, May 4, 2006. The study examined the following five areas: life sciences, mathematics and statistics, physical sciences, computing sciences, and engineering.

[104] OECD Global Science Forum, *Evolution of Student Interest in Science and Technology Studies Policy Report*, May 4, 2006.

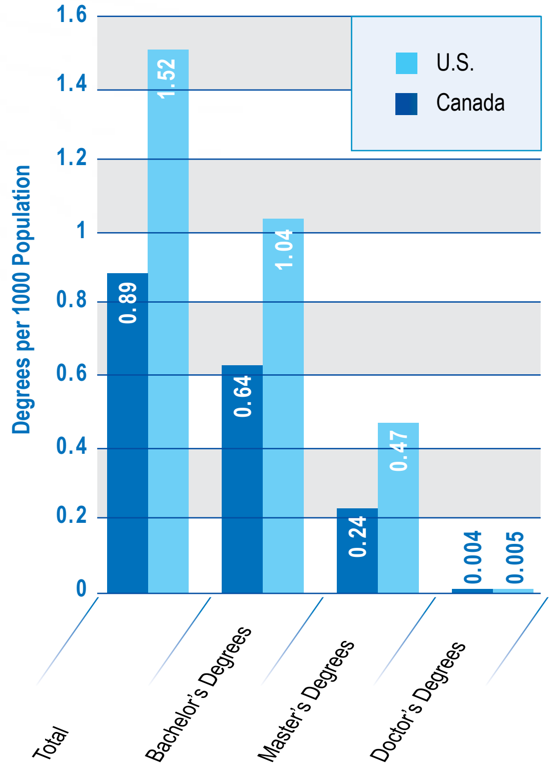
Number of Business Degrees

Good management is a significant driver of demand in an effective innovation system. The Institute for Competitiveness and Prosperity illustrates the importance of management skills in a study that finds that although science and engineering graduates are dominant founders of successful high technology firms, these graduates become less important as firms mature. As companies mature, different sets of skills may be required to keep them growing. It appears that the transition towards leadership with more diverse backgrounds (as opposed to technological ones) is more pronounced in the U.S. Research indicates that a key challenge for growing innovative firms in Canada is access to management talent.

Canada has far fewer degrees in business both at the undergraduate and graduate level than the U.S. (Figure 22). Overall, managers in Canada generally have lower educational attainment than those in the U.S., and CEOs of our largest companies tend to have less formal business education at the graduate level.[105]

The *Financial Times* does a yearly world ranking of Master of Business Administration (MBA) schools, and according to the 2008 ranking, Canada has six MBA schools in the top 100, which is an increase from four in 2000. While the number of Canadian MBA schools in the top 100 has increased, their rankings have continued to decrease since 2004 (Figure 23).

Figure 22: Business Degrees Granted per 1000 Population, by Levels of Degrees (2003–04)



Source: Institute for Competitiveness & Prosperity analysis, "Strengthening Management for Prosperity," 2007.

Figure 23: Ranking of Canada's Top MBA Schools, 2004, 2007 and 2008

School	2008	2007	2004
University of Toronto	40	27	21
York University	48	49	22
University of Western Ontario	53	41	29
University of Alberta	88	-	97
University of British Columbia	92	77	67
McGill University	96	90	39

Source: *Financial Times*, Business School Rankings, www.ft.com/businesseducation/mba.

[105] R. Martin and J. Milway, *Strengthening management for prosperity,* Institute for Competitiveness & Prosperity (May 2007).

Managers with International Work Experience

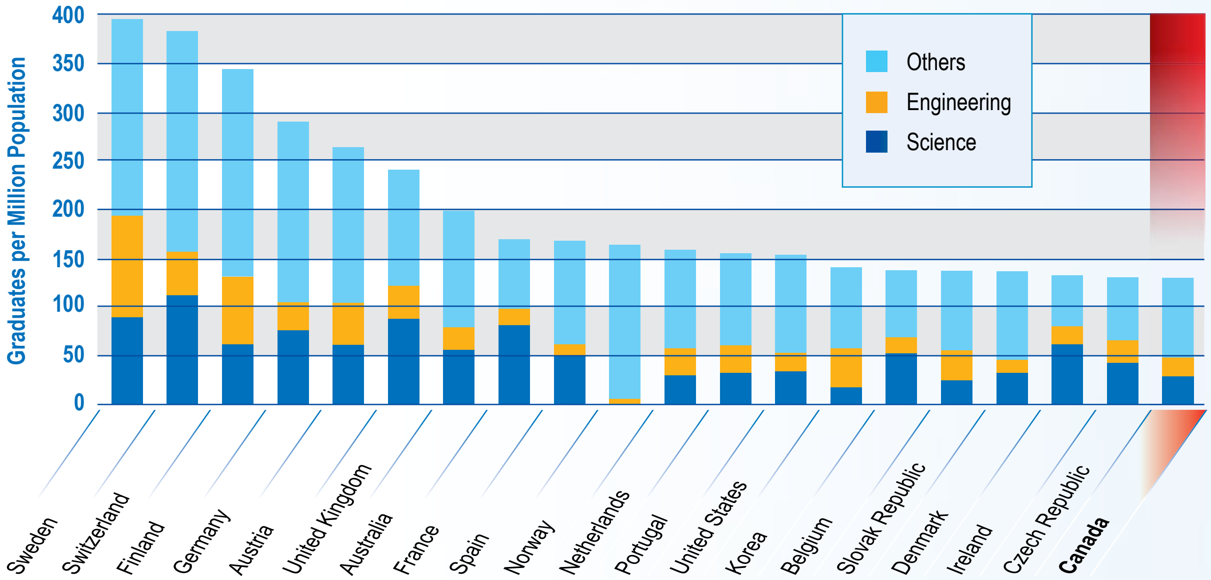
Research suggests that the ability of a CEO to operate at a global level is greatly enhanced by having prior international work experience. Survey results drawn from the CEOs of the 700 largest U.S. companies find that from 2003 to 2004, there was a 9 percent increase in the number of CEOs with international experience, amounting to a total of 30 percent.[106]

A recent study commissioned by Russell Reynolds Associates,[107] examined how the globalization of the Canadian economy influenced the competencies sought in CEOs, succession planning and the professional development of the senior executives of Canada's largest firms. They found that over the past 20 years, Canada's largest companies have become significantly more global. The share of Canadian CEOs with international work experience grew from 25 percent in 1987 to 37 percent in 2007. However, despite the increase in Canadian CEOs with international work experience, the rate of the increase has slowed. [108]

Number of Doctoral Degrees

The importance of PhD training in the global knowledge-based economy is reflected in the increasing number of people acquiring PhDs worldwide. From 1996 to 2006, the number of working-age (25–64 years old) Canadians with earned PhDs grew from 90 945 to 142 180.[109] Much of this growth in PhD holders in Canada has come through immigration, and despite the growth in PhD holders as a share of the population, Canada ranks 20th in the number of new PhD graduates per million population in the OECD, as shown in Figure 24.

Figure 24: PhD Graduates per Million Population, Top 20 OECD Countries



Source: OECD, Science, Technology and Industry Outlook, 2006.

106 J. Martin, The global CEO: overseas experience is becoming a must on top executives' resumes, BNET, January–February 2004, accessed at http://findarticles.com/p/articles/mi_m4070/is_195/ai_114050442.

107 Russell Reynolds Associates, *A World of Experience — The Globalization of Canadian Corporate Leadership: 1987–2007 Study* (2008). The study, conducted by researchers at King's University College and the Richard Ivey School of Business at the University of Western Ontario examined the international experience of the CEOs of Canada's 100 largest for-profit corporations, whose revenues of more than $718 billion are equal to approximately 55 percent of the country's Gross Domestic Product. The study sample was restricted to companies headquartered in Canada; subsidiaries of foreign corporations were excluded. In order to identify trends over time, the study examined CEO international experience in 1987, 1997 and 2007.

108 Russell Reynolds Associates, *A World of Experience — The Globalization of Canadian Corporate Leadership: 1987–2007 Study* (2008).

109 AUCC communication, based on Statistics Canada census data for 1996 and 2006.

The low graduation rates of PhDs in Canada may be a reflection of the low business demand for PhDs relative to the U.S. In 2000, the share of PhDs in full-time, full-year employment was lower in Canada than in the U.S. (0.8 percent versus 1.1 percent). Between 2001 and 2006, the number of adults aged 25–64 who held a doctoral degree in Canada increased by 30 percent.[110]

Internships and Co-Ops

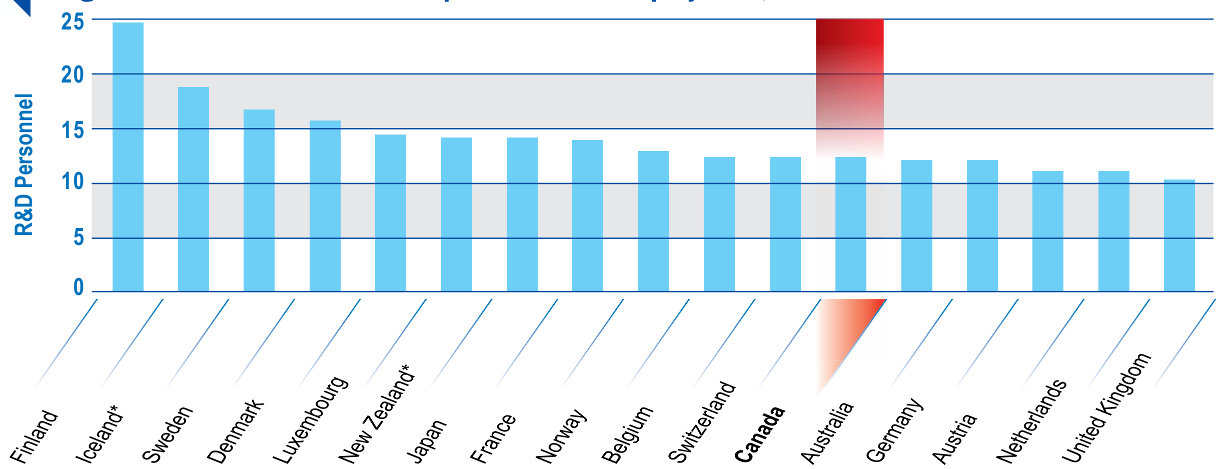
Just as it is important to build up Canada's stock of skilled and talented people, it is equally important to provide them with opportunities to learn and apply their skills. As the Association of Universities and Colleges of Canada states, internships and co-ops "enhance employment opportunities for graduates, provide the labour market with the essential skills and competencies it requires, and improve private sector receptor capacity for the results of university research." [111]

Although data on internships and co-ops are not well established, some universities and firms are beginning to track these data. According to the Canadian Association for Co-operative Education, there were 80 000 co-op students in Canada in 2006, which is an increase from about 53 000 a decade ago. Of the 80 000 co-op students, almost 74 percent are in Ontario (58 percent) and British Columbia (16 percent).[112] Many are placed within the private sector.

Researchers in the Workforce

Countries with strong high-technology sectors, such as Finland, Japan and Sweden, have among the highest densities of researchers. As Figure 25 shows, Canada places in the lower middle of the pack in the total R&D personnel per thousand people employed. Like most other OECD countries, the majority of Canada's researchers are in the business sector, followed by the higher education sector. In 2005, the business sector provided employment to 64 percent of all researchers in Canada. This share has been increasing since 1996, as highly skilled individuals become more integral to a business's innovation process.[113]

Figure 25: Total R&D Personnel per Thousand Employment, Selected OECD Countries (2004)



* Reference year is 2003.

Source: OECD, Main Science and Technology Indicators, 2008/1.

Note: Data for U.S. not available.

110 *Momentum: the 2008 report on university research and knowledge mobilization*. Association of Universities and Colleges of Canada, p. 116.

111 *Momentum: the 2008 report on university research and knowledge mobilization*. Association of Universities and Colleges of Canada.

112 Canadian Association for Co-operative Education (CAFCE) national post-secondary co-operative education database, http://www.cafce.ca/pages/surveys.php.

113 Statistics Canada, *Science Statistics: May 2008 edition*, Catalogue no. 88-001-X, vol. 32, no. 1. Analysis by the Council of Canadian Academies, in Business Innovation in Canada, using data from the OECD Main Science and Technology Indicators, and OECD Science, Technology and Industry Scoreboard 2007, shows that there is a strong correlation between business enterprise researchers per 1000 people employed and BERD intensity. Many of the countries with the strongest BERD intensity, such as Finland, Sweden, the United States, Japan, Denmark and South Korea have much higher business enterprise researchers per 1000 people employed ratios than Canada.

Internationally Recognized Distinguished Awards

Another important indicator of Canada's science, technology and innovation performance is the degree to which Canada receives and gives internationally recognized distinguished awards.[114] In the 1960s, Canadians received 20.3 percent of all awards, a figure that dipped to 11 percent in the 1980s, and has risen back to 20 percent since 2001.[115] Canadians have been most frequently recognized in the fields of the environment (2nd in the world after the U.S.), medicine and technology (3rd in the world after the U.S. and the U.K.).

In terms of distinguished science awards, however, Canada ranks lower (12th in the world, tied with Israel). During the period of 1941 to 2008, Canada has received 19 awards in science, in contrast with other countries such as the U.S. (1403), U.K. (222), France (91), Germany (75) and Australia (42). Canada last received a Nobel Prize in science in 1994, when Bertram Brockhouse won the Nobel Prize in Physics for the development of neutron spectroscopy. In 2008, Anthony Pawson, a professor of medical genetics and microbiology at the University of Toronto, was awarded a Kyoto Prize in the basic sciences category for his work on signal transduction, or how cells use chemical signals to regulate one another's behaviour.

Finally, compared to their international (and particularly to their U.S. counterparts), Canadian corporations sponsor very few internationally recognized distinguished awards.[116] Canada confers only two distinguished international awards[117] in the area of science and innovation: the Canada Gairdner International Award for medical research, which is open to candidates outside Canada, and the Manning Innovation Award, which is restricted to residents of Canada. The Canada Gairdner Foundation Award is recognized as one of the world's most prestigious awards in biomedical science. The Manning Innovation Award has, since 1982, been recognizing those who develop and successfully market a new concept, process or procedure in Canada.[118] The International Congress of Distinguished Awards notes that throughout the world (especially in the U.S., Japan, Netherlands, Sweden and Switzerland) "national and international corporations have seen it as part of their role in the world to sponsor awards and prizes that become synonymous with their corporate names and logos." [119]

The Canada Gairdner Foundation Award is recognized as one of the world's most prestigious awards in biomedical science.

[114] The International Congress of Distinguished Awards (ICDA) defines these as awards that have a minimum cash award of US$100 000, are presented on a recurring basis, employ a broad-based nomination process, maintain an independent, merit-based evaluation and selection process involving well-qualified jurors, and recognize achievements that are primarily of international importance; and are committed to promoting knowledge and understanding for all people.

[115] ICDA's list of internationally distinguished awards available to Canadians includes 171 separate awards in all fields, including humanitarian and peace awards, and awards in the fields of literature, arts, culture, etc.

[116] In 2007, Canadian corporations sponsored awards totalling US$80 182, which ranks 10th in the world, but, by way of comparison, Sweden was 9th, with US$222 219 in corporate-sponsored awards.

[117] As identified through a series of criteria developed by the ICDA in 1999. These awards are considered as one of the world's most important awards; the award's recipients are "distinguished world laureates"; and the recipient's home institution is the employer of a "distinguished award laureate."

[118] Past Manning Award winners of the main $100 000 "Principal Award" include Janusz Pawliszyn (2008) for solid-phase micro extraction (SPME), an environmentally friendly, convenient and efficient technology for collecting and extracting samples for chemical analysis, and Mike Lazaridis and Gary Mousseau (2002) for the development of the BlackBerry.

[119] Larry E. Tise, International Congress of Distinguished Awards, *Awards Canada 2008: An Analysis of the Participation of Canada and Canadians in the World of Awards*, prepared for Industry Canada, June 2008, p. 18.

Regenerative Medicine

Regenerative medicine is an emerging field that aims to "repair, replace, and/or regenerate" damaged tissues and organs by stimulating previously irreparable organs into healing themselves. It holds the potential to treat previously chronic diseases and conditions including Alzheimer's disease, diabetes, heart disease, renal failure, osteoporosis and spinal cord injuries.

Since the 1960s, Canadian medical researchers have been at the forefront of regenerative medicine. James Edgar Till and Ernest Armstrong McCulloch were the first researchers to identify the haematopoietic stem cell. Today, several of the world's leading stem cell biologists are located in Canada including Freda Miller who identified stem cells in the skin, Derek van der Kooy who discovered stem cells in the retina, and Sam Weiss, who identified stem cells in the brain. Expertise in stem cell biology is complemented by leadership in tissue engineering/biomaterials. Michael Sefton was awarded the Killam Prize in 2008 for his outstanding career achievement in tissue engineering.

Attracting International Talent

Canada has historically been able to attract the labour supply it needs through immigration, but this is changing. Skilled immigrants and top-ranked international students are now highly sought after by many countries, including those not previously considered as destination nations. Several countries have streamlined their immigration policies and have instituted incentives to attract and retain international students.

Photo: Trudee Lee Photography

Dr. Samuel Weiss, **PhD, Professor of Cell Biology and Anatomy and Pharmacology and Therapeutics, University of Calgary, Calgary, Alberta**

Sparking interest and inspiring students to explore education and careers in science-related fields is key to growing Canada's base of knowledge workers.

Dr. Samuel Weiss, recipient of the 2008 Gairdner International Award for his discovery of adult neural stem cells in the mammalian brain and its importance in nerve cell generation, recalls how a course on neurochemistry he took as an undergraduate biochemistry major inspired his career path.

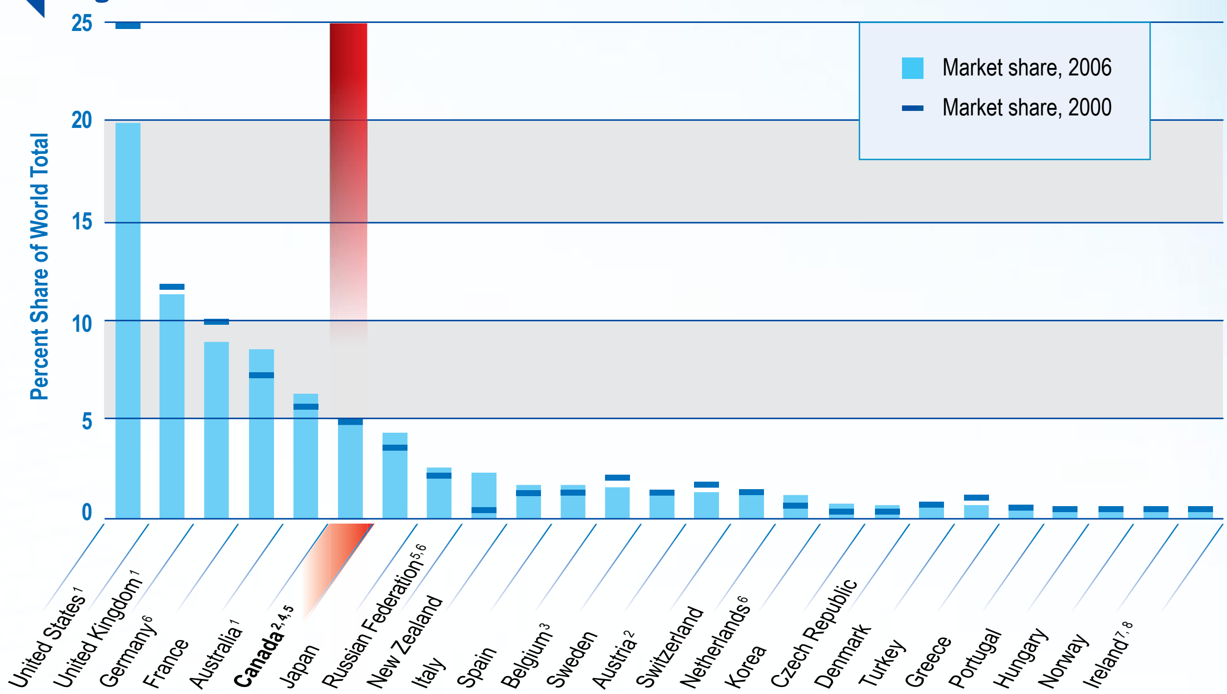
"The course was lectured/coordinated by two giants — Leonhard Wolfe, who provided the understanding of how prostaglandins regulate central nervous system (CNS) function — and Theodore Sourkes, who was instrumental in identifying dopamine depletion as the key chemical pathology of Parkinson's disease. I was blown away by the course, and what those two professors taught me. From that point on, I became a lifelong sponge for information linking biochemistry and the nervous system."

International Student Enrolment

Figure 26 shows that Canada's market share of the world's international students has remained virtually the same (5 percent in 2000; 5.1 percent in 2006). The U.S. (20 percent) and the U.K. (11.3 percent) have much higher shares, and Australia has seen significant growth over this six-year period, from 5.6 percent in 2000 to 6.3 percent in 2006.[120]

Canada's relative position in the market share may be partially attributed to its modest promotional activities when compared to the aggressive and strategic promotional activities of the U.S.,[121] U.K. and Australia, which are the leading destinations.

Figure 26: Trends in International Education Market Shares



Note: The proportion of students abroad is based only on the total of students enrolled in countries reporting data to the OECD and UNESCO Institute for Statistics.

1. Data by country of origin relate to international students defined on the basis of their country of residence.
2. Excludes tertiary-type B programmes.
3. Excludes data for social advancement education.
4. Reference year 2005.
5. Excludes private institutions.
6. Excludes advanced research programmes.
7. Data by country of origin relate to international students defined on the basis of their country of prior education.
8. Excludes part-time students.

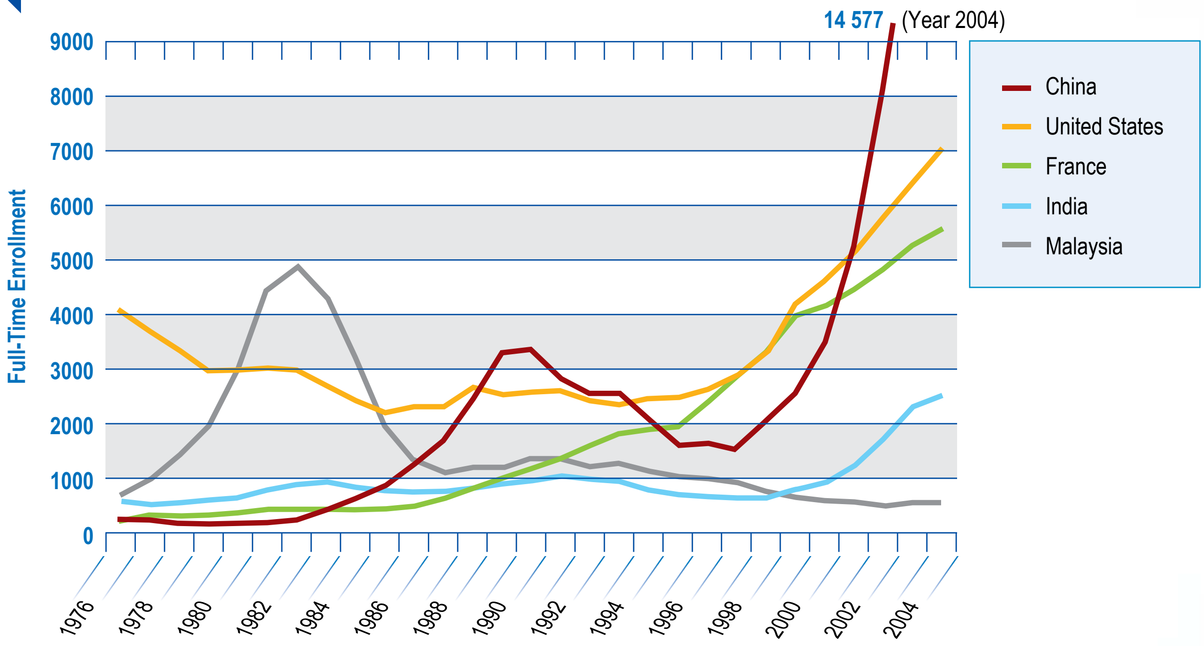
Source: OECD, Education at a Glance, 2008.

[120] OECD, *Education at a Glance, 2008.*

[121] The intake of foreign students by the traditionally dominant U.S. was affected by the tightening of the conditions of entry for international students in the aftermath of the events of September 11, 2001.

Figure 27 shows the country of origin of visa students in Canada from various destinations. The Observatory on Borderless Higher Education notes that U.S., U.K. and Australia strategically target students in potentially high-yield countries such as China and India. All three countries have implemented initiatives to facilitate integration of international students, such as changes in the immigration requirements and processes.[122]

Figure 27: Country of Origin of Visa Students in Canada



Source: AUCC, "Trends in Higher Education, Volume 1: Enrolment," 2007, based on Statistics Canada data.

Recent and well-received initiatives by the Canadian government to enable universities to attract and to retain international graduate students and researchers include the changes made to the Post-Graduation Work Permit Program. This program will make it easier for international students who have graduated from an eligible program at a post-secondary institution to gain valuable Canadian work experience. These changes include: extending the duration of the work permit to three years (in some cases); providing the flexibility for new graduates to work in any field; and removing the requirement to have a job offer. Finally, a new immigration category, which facilitates the transition to permanent residence for skilled foreign workers and students who have already proved employable in Canada, has just been created. The Canadian Experience Class immigration stream is expected to grant permanent resident status to 7500 economic immigrants in 2009, a figure that is forecast to rise to 25 000 annually over time.[123]

While Canada has increased its share of international students over the years, the Canadian Bureau for International Education (CBIE)[124] found that only a third of international students graduating from a Canadian university will attempt to stay in Canada. Many students are deterred by inconsistent and confusing policies and practices. Many employers are not aware that they are allowed to hire international students and graduates. The CBIE also found that employers who have hired international graduates sometimes report that current U.S. border policies have blocked some employees from carrying out company business in the U.S.[125] Canada is not capitalizing on the immense talent offered by these international students.

122 The Observatory on Borderless Higher Education, OBHE, 2007 as cited by Smita Bhatia, *A Comparative Analysis of Canada's Capacity for Supporting International Students and Researchers*, 2008.

123 http://www.cic.gc.ca/english/resources/publications/annual-report2008/section1.asp#part1_4.

124, 125 S. Bond et al., *Northern Lights: International Graduates of Canadian Institutions and the National Workforce*, Canadian Bureau for International Education (2007).

The Government of Canada established the Canada Excellence Research Chairs (CERC) Program in September 2008 to help Canadian universities attract and retain the world's top researchers. CERC will award 20 Chair holders and their research teams with up to $10 million over seven years to establish ambitious research programs at Canadian universities. The Vanier Canada Graduate Scholarship (Vanier CGS) Program awards 500 Canadian and international doctoral students scholarships valued at up to $50 000 per year. The Canada Research Chairs (CRC) Program, in which the government invests approximately $300 million each year, also serves to attract high-calibre domestic and international talent to Canadian universities. In June 2007, there were 1837 active Canada Research Chairs, with 584 of the Chair holders having been recruited from outside of Canada, of which 269 of these international recruits being expatriated Canadians.

In addition to attracting and retaining international students, Canada must also make the most of the skills of immigrants. Foreign credential recognition is essential to meet the needs of the 21st century economy. Of the 1.2 million immigrants that came to Canada with the intention to work between 1997 and 2007, one-third had professional qualifications, and at least half of these sought work in fields requiring some form of training or formal credential.[126] Canada must ensure that internationally trained workers can fully participate in the labour market and in Canadian society.

In 2008, British Columbia devoted additional funds to improving its international credential recognition programs. Saskatchewan also announced a pilot project that will recognize international credentials of immigrants before arriving in Canada. The Government of Canada recently provided $1.2 million in funding for projects to improve foreign credential recognition processes in Canada.[127] These projects aim to: improve the dissemination of information; identify the programs and services available in colleges or institutions that prepare immigrant students to integrate into the labour force; investigate issues related to the entry of foreign-trained practitioners; and develop an entry-to-practice examination for competency assessment in specific occupations.

Canada's Innovation Performance Challenge

State of the Nation 2008: Canada's Science, Technology and Innovation System **is a fair, balanced picture of the strengths and weaknesses of our performance on a wide range of science, technology and innovation indicators. The picture that emerges from our first report is that, for almost all indicators we track in our first report, Canada is a solid, middle-of-the-road performer. Our strengths in these areas have greatly improved our productivity, our standard of living, and our quality of life. But Canada is not the only country that has recognized the importance of science, technology and innovation to economic and social well-being. Other countries, both developed and emerging, have also made investments and policy changes in science, technology and innovation the centrepiece of their economic strategy, particularly to help them rebound from the current global recession. So, while we have been good, we now need to be great. Changes in technology, in the nature of global competition, in immigration flows, and the knowledge requirements of new jobs demand that we keep pressing forward. Improving our performance and our international rankings in these indicators will require a concerted, coordinated effort by Canadian business, higher education, government and non-profit institutions. It is a challenge we should welcome. We look forward to reporting on our progress in the** ***2010 State of the Nation Report.***

126 Hawthorne, Lesleyanne. "Foreign Credential Recognition and Assessment: an Introduction," *Canadian Issues*, Spring 2007, p. 3.

127 For more details on these programs, read the Citizenship and Immigration Canada backgrounder at http://www.cic.gc.ca/english/DEPARTMENT/media/backgrounders/2008/2008-05-30.asp.

Annex 1: Building Canada's Advantages

In its 2007 S&T Strategy, *Mobilizing Science and Technology to Canada's Advantage,* the Government of Canada committed to fostering three specific S&T advantages for Canada:

- ***Entrepreneurial advantage:*** Canada must translate knowledge into practical applications to improve our wealth, wellness and well-being.
- ***Knowledge advantage:*** Canadians must build upon our research and engineering strengths, generate new ideas and innovations, and achieve excellence by global standards.
- ***People advantage:*** Canada must grow its base of knowledge workers by developing, attracting and retaining the highly skilled people we need to thrive in the modern global economy.

As described in the Strategy, science, technology and innovation leadership must follow an approach that includes the following principles:

- ***Promoting world-class excellence:*** Canada must ensure that it inspires and assists Canadians to perform at world-class levels of scientific and technological excellence.
- ***Focusing on priorities:*** Canada must continue to play an important role in supporting basic research across a broad spectrum of science. To enhance our success, we must be more focused and strategic — targeting more basic and applied research in areas of strength and opportunity.
- ***Encouraging partnerships:*** Canada must support S&T collaborations involving the business, academic and public sectors, at home and abroad. Partnerships are essential to lever Canadian efforts into world-class successes and to accelerate the pace of discovery and commercialization in Canada. Through partnerships, the unique capabilities, interests and resources of various and varied stakeholders can be brought together to deliver better outcomes.