LOOKING TO THE FUTURE:
CANADA’S INNOVATION ECOSYSTEM

The University of Alberta’s submission to the
EXPERT PANEL FOR THE REVIEW OF FEDERAL FUNDING TO RESEARCH AND DEVELOPMENT

February 18, 2011
Annexes

Annex 1 - Connecting the Dots between University Research and Industrial Innovation - Jorge Niosi

Annex 2 - Meeting Canada’s Full Potential: Building World Class Partnerships - University of Alberta’s submission to the House of Commons Standing Committee on Finance

Annex 3 - Entrepreneurial Impact: The Role of MIT - Edward B. Roberts and Charles Eesley - Kauffman Foundation of Entrepreneurship


Executive summary

Sustaining and improving Canada’s competitiveness in the global context increasingly relies upon our ability to create and promote new ideas. However, there are elements in Canada’s innovation ecosystem that are compromising our economic growth and productivity which, in turn, are putting our prospects for continued quality of life at risk. In this submission, the University of Alberta recommends several measures to improve the current situation, including restructuring current federal R&D funding models and programs. The recommendations proposed by the University of Alberta are aimed at enhancing opportunities for solution-driven research while protecting resources for discovery research, promoting knowledge circulation within the innovation ecosystem, encouraging commercialization of knowledge and increasing the movement of talent between industry and universities.

The recommendations

1. Create a Canadian Competitiveness and Productivity Council that would draw its membership from the leadership of key business sectors, government and academia to provide sustained vision, oversight and policy advice on Canada’s competitiveness, assess the effectiveness of government policy and investments in R&D and evaluate the success of private sector growth.

2. Shift investments from SR&ED tax breaks into a Business Research and Innovation Program that would assist in the creation of more Canadian research-intensive companies, encourage the growth of small and medium enterprises to become globally competitive and fuel entrepreneurship in business, government laboratories, universities, and the wider post-secondary sector.

3. Create an Innovation Chairs program through the expansion of NSERC’s IRC program to SSHRC and CIHR. Innovation Chairs would include industry-academic collaboration in science, engineering, health sciences, the arts, humanities and social sciences.

4. Distinguish NSERC funding of solution-driven research from basic discovery research, ensuring that both are appropriately supported incorporating suitable incentives and performance measures.

5. Fund entrepreneurship programs at universities to create an innovation ecosystem on the MIT model. Funding should be provided on a competitive basis, linked to Tri-Council funding, with clearly defined performance measures.

6. Improve access to early-stage angel financing and expertise, review the expansion stage venture capital market in Canada and remove barriers to foreign venture capital investment as per recommendations by the 2005 Expert Panel on Commercialization.

7. Expand NSERC Industrial Postgraduate scholarships and the MITACS and NCE industrial internship programs to SSHRC and CIHR to give students in all fields of study the opportunity to work in business and industry over the course of their programs.

The innovation ecosystem

A high-performance innovation ecosystem is a web of business, university and government interaction in which each partner provides the necessary ingredients to foster innovation, entrepreneurship and competitiveness. Indeed, where each sector excels in their base operations, research and commercialization works for the benefit of society. The strength of universities lies in their ability to create knowledge in a wide spectrum of fields and to push the boundaries of understanding towards improvements and advancements for society. Industry transforms scientific, business, and social innovations into products for society. Critically, government provides the fiscal, macroeconomic and regulatory regime that make up the infrastructure of innovation. It is the effective integration and fine tuning of these activities that will ultimately improve Canadian quality of life. However, there are several indicators in the Canadian economy that demonstrate that the Canadian innovation ecosystem is not thriving in the way it must for Canada to maintain and grow its productivity. In essence, knowledge is not moving well enough within the innovation ecosystem.

The foundation of innovation

Innovation has at its core the advancement of economy, society and well-being. Indeed, as Kevin Lynch recently stated, “Our living standards tomorrow will be shaped by how well we establish our innovation architecture today”. The integration of scientific, technological, business and social innovation is key to building a sustainable knowledge-based society. A high-performance innovation ecosystem based on the circulation of knowledge between the public and private sectors, between research lab or library and society, between campuses and companies is essential to improving our competitiveness and quality of life.

The Canadian government has been seeking to improve the health of Canada’s innovation ecosystem through policy and in recent years has asked for advice on the matter from expert panels. While the Expert Panel on Commercialization chaired by Joseph Rotman, the Competition Policy Review Panel chaired by Red Wilson and other similar endeavours have provided valuable and sound advice, Canada lacks a body that provides sustained vision, oversight and policy advice on the nation’s competitiveness. Indeed, a body that could regularly assess the effectiveness of government policy and investments in R&D while evaluating the success of private sector growth would allow the Government of Canada to be more innovative and responsive in meeting new needs or opportunities.
**Recommendation:** Create a Canadian Competitiveness and Productivity Council that would draw its membership from the leadership of key business sectors, government and academia to provide sustained vision, oversight and policy advice on Canada’s competitiveness, assess the effectiveness of government policy and investments in R&D and evaluate the success of private sector growth.

Canada’s investment in higher education R&D is the highest among G-7 countries and has seen excellent returns: “In Canada, an econometric study has estimated that the $5 billion invested in university research in 1993 increased the gross domestic product by over $15 billion annually, largely through its positive impact on business innovation”. While direct government funding has produced a marked increase in university research and commercialization results with the accompanying impacts on business, the SR&ED tax credit program has been less effective than hoped for in stimulating business R&D investment across a broad spectrum of industry sectors. As a result, there needs to be a reassessment and re-alignment of direct and indirect funding mechanisms for R&D in Canada so that more emphasis is placed on direct rather than indirect R&D support.

The OECD reported that Canadian gross domestic expenditure on R&D per capita (GERD) has declined as a share of GDP since 2005 to 1.8 per cent as compared to innovation leader Finland’s GERD of 3.7 per cent. Canadian business expenditures on R&D (BERD) fell to 1 per cent of GDP in 2008, below the OECD average of 1.6 per cent and well below Finland’s BERD rate of 2.8 per cent. There is a strong correlation between BERD and patent activity which is an important source of new products and services. For example the OECD reported that in 2008 Canada produced 19 triadic patents per million population while Finland generated 64 triadic patents per million population, almost double the OECD average. Other innovative economies such as Germany and Switzerland also have a high rate of patent production.

In comparison to international competitors, one of the perennial problems of the Canadian economy is that, although small and medium enterprises (SMEs) make up the majority of businesses in Canada, they are not primed as receptors for the knowledge and innovation being produced in the nation’s universities. As a result, they are less likely to produce or adopt innovations: Canada’s “[…] sluggish productivity record in the last twenty years is almost certainly related to the slow adoption by SMEs of advanced technology.”. For an in-depth discussion of this situation, see Annex 1 for the paper “Connecting the Dots between University Research and Industrial Innovation”.

The U.S. federal government’s Small Business Innovation Research Program (SBIR) is one example of a national program that uses direct support to create innovation opportunities for SMEs. Through this program SMEs are encouraged to both engage in and absorb high level basic and applied research. SBIR succeeds in achieving three major commercialization objectives:

- SBIR effectively links SMEs to the research community using important aspects of the “open innovation” model. The SMEs, rather than their university partners, identify technical and scientific innovations that have the greatest potential to respond to market demands.
- SBIR provides entrepreneurs and SMEs a way to bridge the funding “valley of death,” which often prevents a concept from progressing from the prototype stage to product development.
- When successful, the process leads to the development of new companies or the growth of established ones.

Developing a Canadian version of SBIR that takes into account our unique innovation architecture would be instrumental in overcoming the factors slowing the growth of our innovation ecosystem. The Canadian Competitiveness and Productivity Council, the formation of which is recommended above, could play an instrumental role in the design of such a program.

**Recommendation:** Shift investments from SR&ED tax breaks into a Business Research and Innovation Program that would assist in the creation of more Canadian research-intensive companies, encourage the growth of small and medium enterprises to become globally competitive and fuel entrepreneurship in business, government laboratories, universities, and the wider post-secondary sector.

**The role of universities in entrepreneurship and innovation**

Canada’s post-secondary institutions are the foundation for advancing research and innovation in society. Society’s need for basic research will not diminish: publicly-funded research pushes the boundaries of knowledge which in turn seeds technological innovations. Increasingly, private sector R&D is shifting focus from discovery research, which is expensive, high risk and long term, to near-market product development. Therefore, it is critical that governments continue to support curiosity-driven research conducted at universities; universities are able to provide the sophisticated infrastructure and expertise to conduct ground-breaking research. As major corporations and industry move away from in-house
R&D, collaborations with universities become ever-more important in developing ideas, innovations, and inventions for the marketplace.

Cooperative research programs such as NSERC’s Collaborative Research and Development Grants and Industrial Research Chairs (IRCs) have been effective in bringing together academic and industry researchers to push the boundaries of knowledge and, along the way, find solutions to industrial problems. These programs help to break down the cultural divide between universities and businesses by encouraging open and collaborative interaction at a pre-commercial stage of research. Industry is actively involved in research programs, informing the process, and acting as a receptor when ideas are ready for commercial applications.

Companies in many sectors have benefited from IRCs as they enable productive collaborations between top researchers and industry. For example, University of Alberta researchers have found, and continue to work on, solutions to problems encountered by the energy sector (with a particular emphasis on the wide range of issues faced by the oil sands industry), power generation and the construction industry. IRCs have been successful in establishing industry-relevant research and education programs and circulating knowledge and technology in the innovation ecosystem. Indeed, the NSERC model for these programs should be expanded and incorporated into CIHR and SSHRC funding streams, in order to leverage these benefits for the health sciences and the arts, humanities and social sciences.

Recommendation: Create an Innovation Chairs program through the expansion of NSERC’s IRC program to SSHRC and CIHR. Innovation Chairs would include industry-academic collaboration in science, engineering, health sciences, the arts, humanities and social sciences.

One shortcoming of the IRC program is that, by definition, it supports and is supported by existing industry, thereby missing vital opportunities to develop solutions that might generate entirely new industries. There is a close link between engineering, computing science and physics research and its—often direct—application to industry and societal issues. For example, three researchers at Bell Laboratories, searching for a replacement of vacuum tubes in telecommunications infrastructure, invented the transistor which transformed electronics and revolutionized computer design. They were awarded the Nobel Prize for Physics in 1956 for the discovery. Similarly, a researcher at Standard Telecommunication Laboratories discovered the way to use fibre optic cables to transmit vast amounts of data. His work shaped the modern communications network and earned him the Nobel Prize in Physics in 2009. Truly, solution-driven research results in the patents that drive the creation of revolutionary industries.

In fact, universities that do not have a strong focus on engineering and technology have relatively low patenting output and consequently a lower likelihood of generating disruptive technologies and new industries. In 2009, Harvard University and Johns Hopkins University—both of which are strong in the life sciences and medicine, but not in engineering or physical sciences—were issued approximately 46 patents each, while the Massachusetts Institute of Technology (MIT) was issued 154, and the California Institute of Technology was issued 94 patents. Moreover, of the company founders who graduated from MIT in the last fifteen years, 44 per cent are engineers, 32 per cent are from social sciences and management studies, and less than 5 per cent have life sciences degrees. It is interesting to note that 59 per cent of alumnus-creating biotech and medical companies were founded by engineers while only 10 per cent by life-sciences graduates.

These results support the need for solution-driven research in the Canadian innovation environment. Further resources from the restructuring of the SR&ED tax credit should be invested in the Tri-Councils with a focus on solution-driven research and its commercial application. Performance measures for assessing research proposals must be distinct and innovation-focused as compared with basic discovery research which is generally measured by peer-reviewed publications. To facilitate this, NSERC should set up funding pillars similar to CIHR’s pillars of biomedical sciences and clinical research, so as to appropriately support both discovery research and applications-based research.

Recommendation: Distinguish NSERC funding of solution-driven research from basic discovery research, ensuring that both are appropriately supported incorporating suitable incentives and performance measures.

At the same time, it is vital that we develop efficient methods for translating the new knowledge generated at universities into usable products, processes and services. Canadian universities have successfully contributed to scientific discoveries that advance the frontiers of understanding but they continue to under-perform in mobilizing the knowledge that benefits society through patents, licenses, spinouts, and knowledge transfer. In a recent patent activity survey by the Association of University Technology Managers, Canadian universities were collectively issued 120 patents in 2009. This figure was considerably less than the 154 patents issued to MIT, the 244 issued to the University of California system or the University of Wisconsin, Madison, a public university which was awarded 119 patents, nearly equal to the entire
Canadian university system. These indicators show that an entrepreneurial culture coupled with a strong research base in science, engineering, management, arts and social sciences is necessary for Canadian universities to compete on the world stage.

Strong linkages with international networks that leverage our world-leading R&D and knowledge creation will ensure that Canadian businesses and universities are capable of facing the challenges posed by rapid changes in the global economy. To take advantage of opportunities for strategic global partnerships, government support, as modeled by Alberta Innovates, needs to be nimble enough to leverage appropriate funds in a timely manner. The pursuit of international partnerships with the best and brightest, combined with the development of a strong and interactive national entrepreneurial culture will be critical to Canada’s success in developing an internationally competitive environment for innovation (see Annex 2 for the University of Alberta’s pre-budget submission on international partnerships).

The Massachusetts Institute of Technology (MIT) provides a powerful illustration of the effectiveness of a university-anchored innovation ecosystem within the global context. MIT’s entrepreneurial culture and record of innovation is the well-spring of entrepreneurship for its graduates. A recent study\(^9\) conducted by the Kauffman Foundation of Entrepreneurship on the entrepreneurial impact of MIT estimates that MIT alumni are responsible for the creation of 28,500 currently active companies that employ 3 million people and generate global revenues of $2 trillion which is equivalent to the world’s eleventh-largest economy. MIT alumni create knowledge-based companies in software, biotechnology, manufacturing, or consulting that spend on average 24 per cent of their revenues on R&D, generate patents, and export a high percentage of their products (see Annex 3 for the complete case study).

MIT’s success arises from a well-developed innovation ecosystem consisting of a network of well-funded and high-performing offices that mutually support entrepreneurship within the university and with MIT’s industrial partners. These include:

- **Technology Licensing Office** - grants licenses to both existing and startup companies that demonstrate the technical and financial capacities to develop MIT’s early-stage technology into commercially-successful products.

- **Deshpande Centre for Technological Innovation** - reduces technology and market risk by funding early-stage research and facilitates connections between researchers and the business/venture capital community.

- **MIT Entrepreneurship Centre** - fosters entrepreneurship through education programs and builds industry-technology partnerships and networks with the entrepreneurial community.

- **Venture Mentoring Service** - supports innovation and entrepreneurial activity throughout the MIT community by matching prospective entrepreneurs with experienced volunteer alumni mentors.

- **Industry Liaison Program** - creates and strengthens mutually beneficial partnerships between MIT researchers and global corporations.

- **Student groups and innovation prizes** - foster entrepreneurial activity as an integral part of the student experience.

Canada must develop a robust innovation ecosystem based on a foundation of university discovery that mobilizes knowledge and translates invention into social benefit. Emulating models such as MIT, Canadian universities need to implement best practices in commercialization and business development in order to encourage the stimulation and growth of a culture of entrepreneurship within Canada. Funding for university entrepreneurial activities must be examined and leveraged effectively. Programs such as the Centres of Excellence for Commercialization and Research, which have shown lacklustre results, should be replaced with support for a suite of university entrepreneurship programs that create a thriving innovation environment.

**Recommendation:** Fund entrepreneurship programs at universities to create an innovation ecosystem on the MIT model. Funding should be provided on a competitive basis, linked to Tri-Council funding, with clearly defined performance measures.

One of the greatest impediments to commercialization is insufficient angel and venture capital. Furthermore, most venture capital is focused at later stage of development, leaving little opportunity for new start-ups and for moving early-stage technologies towards proof of principal. Angel and venture capital and experienced technology entrepreneurs are in particularly short supply in Canada. This makes the commercialization exercise more difficult for Canadian universities than for their U.S. counterparts. For example, MIT benefits from access to angel investment, largely funded from company founders’ family and friends, and well-developed venture capital funding in the U.S., especially in Massachusetts and California. The 2005 Expert Panel on Commercialization chaired by Joseph Rotman made several recommendations to improve access to early-stage angel financing and expertise, proposed a review of the expansion stage venture capital market in Canada, and suggested removing barriers to foreign venture capital investment. The Expert Panel for
Without necessary changes to Canada’s innovation architecture, Canadian productivity, and therefore Canadian quality of life, will stagnate.

the Review of Federal Support to Research and Development should review and adopt the Rotman recommendations (see Annex 4 for the final report).

**Recommendation:** Improve access to early-stage angel financing and expertise, review the expansion stage venture capital market in Canada and remove barriers to foreign venture capital investment as per the recommendations of the 2005 Expert Panel on Commercialization.

**Talent: the foundation of an innovative society**

A creative and skilled workforce lays the foundation for an innovative society. However, Canada is facing several important challenges on the talent front. One of those challenges is simple demographics: our population is not being renewed at the rate required to sustain our economy. This leads to the necessity of attracting and retaining the best brains locally and internationally. Further, our economy requires more highly educated and talented people than we are currently producing. The Expert Panel on Commercialization raised the valid concern that, while Canada is highly-ranked among OECD countries in terms of the share of the working-age population with post-secondary education, the nation has “[... proportionately fewer university graduates and--at the very high end--[Canada] is producing new PhD graduates at a much slower pace than major competitors [...]]”. Furthermore “[...] there is concern about the extent to which Canada’s universities have the capacity to significantly increase the number of graduate students”.

Finally, there are concerns about the demand for the highly skilled personnel currently being produced by Canada’s universities: according to UNESCO Science Report 2010, the labour market demand in Canada for science and engineering graduate students is falling. This trend needs to be addressed: knowledge and talent interaction gives industry insight into new research and applications and provides students with valuable first-hand experience with commercial issues. Students supported by NSERC Industrial Postgraduate Scholarships and MITACS and Networks of Centres of Excellence (NCE) internships have direct experience working with industry, and become key agents of knowledge mobilization and integrated innovation.

**Recommendation:** Expand NSERC Industrial Postgraduate scholarships and the MITACS and NCE industrial internship programs to SSHRC and CIHR to give students in all fields of study the opportunity to work in business and industry over the course of their programs.

**Conclusion**

Canada’s innovation ecosystem is at an important point in its evolution. Without necessary changes to the Government of Canada’s innovation architecture, Canadian productivity and, therefore Canadian quality of life will stagnate. Optimizing the Canadian innovation ecosystem by engendering a stronger culture of innovation and entrepreneurship will ensure Canada’s position as a leader in the global economy. The Expert Panel for the Review of Federal Support to Research and Development has the opportunity to identify the strengths of all the partners in the Canadian economy – universities, businesses, and government – and in turn leverage their efforts to the benefit of all Canadians.

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1 Kevin Lynch, “Innovate or Perish,” Globe and Mail, 8 Feb 2011
2 Jorge Niosi, “Connecting the Dots between University Research and Industrial Innovation” IRPP Choices Vol. 14, no. 14 (Oct 2008), 5
3 OECD, Science, Technology and Industry Outlook 2010, 163 & 174
4 Ibid
5 Jorge Niosi, “Connecting the Dots between University Research and Industrial Innovation” IRPP Choices Vol. 14, no. 14 (Oct 2008), 16
6 For more information on SBIR, see http://www.sbir.gov/
8 Edward Roberts and Charles Eesley, Entrepreneurial Impact: The Role of MIT, Kauffman: The Foundation of Enterprise (2009), 16
12 UNESCO Science Report 2010: Current Status of Science around the World (2010), 63 (see Annex 5 for the chapter on the Canada)
 Connecting the Dots between University Research and Industrial Innovation

Jorge Niosi

With commentaries by
Indira V. Samarasekera
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This publication was produced under the direction of Jeremy Leonard, Research Director, IRPP and France St-Hilaire, Vice President, Research, IRPP. The manuscript was copy-edited by Zofia Laubitz and Francesca Worrall, proofreading was by Zofia Laubitz and Mary Williams, production was by Chantal Létourneau, art direction was by Schumacher Design and printing was by AGL Graphiques.

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The most important high-level driver of productivity is innovation, which is itself the result of complex and poorly understood interactions between research and development, education, investment and a host of other factors. The goal of this project is to examine the channels by which efforts to improve Canada’s innovation performance can result in productivity improvements.

Innovation and Productivity / Innovation et productivité
Research Directors / Directeurs de recherche
Jeremy Leonard and/et France St-Hilaire

Connecting the Dots between University Research and Industrial Innovation
Jorge Niosi

3 Introduction
4 National Systems of Innovation
4 Hypothesis and Research Questions
5 A Framework for Understanding the Stages of Innovation
6 Universities’ Supply of Science and Technology
9 Demand for University Technology
11 University-Industry Technology Transfer
15 Policy Options for Canada
16 Conclusions
17 Appendix 1 : Channels of Technology Transfer between Academic Institutions and Industry
18 Notes
18 References

Innovation: Enough Talk, Time to Act
Indira V. Samarasekera

24 Notes
24 References

University Research and Industrial Innovation: How Can Canada Compete and Win?
Ilse Treurnicht

26 The US Pipelines Are Different
26 The US Receptors Are Different
27 Made-in-Canada Solutions
29 Résumé
30 Summary
Acronyms

ATP  advanced technology program
AUTM  Association of University Technology Managers
BDC  Business Development Bank of Canada
BERD  business expenditure on R & D
CECR  Centres of Excellence for Commercialization and Research
CIHR  Canadian Institutes of Health Research
HERD  higher education R & D
IRAP  Industrial Research Assistance Program
NIST  National Institute of Standards and Technology
NS & E  natural sciences and engineering
NSERC  National Sciences and Engineering Research Council
NSI  national systems of innovation
OECD  Organisation for Economic Co-operation and Development
OTT  office of technology transfer
R & D  research and development
SBIR  small business innovation research
SME  small and medium-sized enterprise
STTR  small business technology transfer research
UILO  university-industry liaison office
Introduction

Innovation, particularly in science and technology, is the engine of economic growth (Rosenberg 2004). This idea was Robert Solow's contribution, for which he received a Nobel Prize in economics in 1987. Since then, many national and international studies have confirmed his thesis. Economies grow through the adoption of technological innovations, more than through the incorporation of such inputs as capital and labour. Technological innovation accounts for well over 50 percent of economic growth in Organisation for Economic Co-operation and Development (OECD) countries (Pianta 1995). This occurs in two ways: productivity increases as a result of the wide adoption of new technologies, and new industrial products and sectors are created (Saviotti and Pyka 2004).

Universities are essential contributors to technological innovation. They train the labour force and create human capital. As a result of their research activities, new areas are explored, the frontiers of knowledge are pushed forward and sometimes even the foundations of new industries are laid. Yet the channels through which knowledge flows from universities to the economy and back are not well understood.

Among OECD countries, Canada ranks high with regard to funding university research and the number of graduates in the natural sciences and engineering, as well as on some raw indicators of outcomes, such as academic publications. Although some improvements can be made on the supply side, the main problems lie on the demand side. It is far from clear whether these investments in academic research are bearing fruit in terms of improved business performance and productivity. There are relatively few high-technology and science-based companies in Canada. And there is a common perception that Canada lags behind in terms of the commercialization of research, and in productivity.
Hypothesis and Research Questions

In this paper, I will examine the different channels of technology transfer and compare their contribution in Canada with their contribution in other industrial nations. I will try to answer the following questions:

- How effectively do Canadian academic institutions transfer technology to industry?
- How do Canadian institutions compare with other advanced nations in terms of technology production (for example, scholarly publications, patents and licenses)?
- What new sectors and technologies do Canadian universities create, and how do these compare with those created by their foreign counterparts?
- What are the bottlenecks in university-industry technology transfer in Canada? Are these bottlenecks similar to those in other industrial nations?
- Can university-industry technology transfer be improved through policies, and if it can, should these policies focus on the supply or the demand side?

National Systems of Innovation

The production, diffusion, adoption and mastering of technology are most often achieved by industrial firms, but they require a complex institutional and policy environment in order to conduct research and development (R&D) and innovate. This environment — these institutions and policies — are called national systems of innovation (NSIs). NSIs are policies, institutions and organizations devoted to the production and diffusion of new and improved science and technology within the boundaries of states (Lundvall 1992; Nelson 1993; Niosi 2000a; Niosi et al. 1993). Today, the governments of most industrial and some industrializing countries employ the NSI approach in their innovation policies.

Several aspects of the NSI approach need to be outlined. Linkages among the innovators (the focal elements, or nodes, which include research universities, government laboratories and innovative firms) are key. These relationships include personal and financial knowledge and regulation flows among the nodes (Niosi et al. 1993). Most important among these linkages are the interactions between producers and users of innovations, in particular, those between universities, government laboratories and industry (Lundvall 1992). Interaction between the users and the producers is vital because users are among the main sources of ideas for innovation among producers. All of the nodes in the system produce knowledge, and some of them, particularly industrial firms, are also the main users of this technology. The efficiency and effectiveness of the system are heavily dependent upon the fluidity of the linkages, particularly knowledge transfers, between the nodes of the system (Niosi 2002). Thus, the interaction between firms and university and government researchers should send clear signals to the researchers as to the likelihood that a university invention will be commercially useful to the industry.

The role of universities

Universities are central components of the NSI. They create human capital, without which existing technology cannot be absorbed and adapted (Lau 1996). While traditional, low-growth industries demand less education, in the fast-growing new economy of the information technologies — pharmaceuticals and biotechnology, advanced materials and aerospace industries — universities provide the high skills required. In many of these science-based industries, key knowledge is thus created in universities and government laboratories and then transferred to business (Niosi 2000b). Further, in any type of industry, higher education increases the capacity of organizations to adopt high technology and use it efficiently (Lim 1999).

Universities move the frontier of science forward by means of advanced research, and they transfer the results of this activity to industry and society through different channels (see appendix 1 for a more complete list of the channels). Among these channels are:

- University graduates who move into industry
- Publications and presentations at academic conferences and industrial meetings
- Research contracted by industry or government to university researchers
- Industry and government consulting work done by university professors
- University professors moving from university to industry, for short or long periods;
- Scientific instruments developed in universities and then adopted and diffused by industry (Rosenberg, 1994)
- The creation of university-industry research corporations (such as the Canadian Microelectronics
and Jiang 2007). Some universities, such as the Massachusetts Institute of Technology in the United States and Chalmers University in Sweden, are presented as models of institutions that promote economic development by means of the creation of new firms (Agrawal and Henderson 2002; Jacob, Lundqvist and Hellsmark 2003; O’Shea et al. 2007).

A Framework for Understanding the Stages of Innovation

Several authors have mapped the various phases and stages in the innovation process. Figure 1 presents one model that is particularly useful in the Canadian context. The process starts with the first stage, research, which is followed by the second, centred on invention, and the third, focused on early-stage technology development. The fourth stage is product development, and the fifth production and marketing.

The first and second stages I will refer to as the “supply side” of innovation, because this is where ideas are organized into useful concepts, research and discovery. Because the economic value of any given new idea (or group of ideas) is difficult to predict, businesses left to themselves would underfund investments in the supply of innovation. For this reason, governments play a large role in funding (through public and corporate granting councils, government-funded laboratories and, to a lesser extent, angel investors)1 and universities play a relatively large role in performing the research. As will be seen later, Canadian policies seem to be slightly biased toward the supply side.

The fourth and fifth stages can usefully be termed the “demand side” of innovation, because this is where ideas are organized into useful concepts, research and discovery. Because the economic value of any given new idea (or group of ideas) is difficult to predict, businesses left to themselves would underfund investments in the supply of innovation. For this reason, governments play a large role in funding (through public and corporate granting councils, government-funded laboratories and, to a lesser extent, angel investors)1 and universities play a relatively large role in performing the research. As will be seen later, Canadian policies seem to be slightly biased toward the supply side.

The third stage — which is the grey area between the supply and demand for innovation — has sometimes been called “the valley of death,” because it is funded only laterally and scantily, in both the US and Canada. But the problems go well beyond funding: there is often a mismatch between expectations on the demand
Canada also ranks high in terms of business funding as a percentage of all academic research (table 2). In 2004, businesses funded 8.2 percent of university research (much of which takes the form of industry-funded contracts for specific academic projects). This proportion was the fifth-highest among OECD countries and was considerably larger than the proportions of its major trading partners (the United States, the United Kingdom, Japan, and France). One might expect that the fact that industry has a significant side and motivation on the supply side. From the perspective of business, investing in early-stage technologies is risky, because it is difficult and potentially costly to assess their commercial viability. From the perspective of academia, scholars are primarily motivated by a desire to publish in scholarly journals, for which commercial viability is typically not as important as the originality of the discovery. This disconnect between supply and demand of innovation is a major obstacle to effective university-industry technology transfer.

Universities' Supply of Science and Technology

The supply of science and technology by universities, unlike the supply of countable goods such as automobiles, cannot be measured directly. Nevertheless, through indirect indicators we can sketch a partial picture of it, and Canada scores well on some, but by no means all, of these indicators.

Canada is second among OECD countries in terms of its expenditure on university research and development as a percentage of its GDP (table 1). This figure reached 0.70 percent in 2004; it was second only to Sweden’s and nearly double that of the United States. More significantly, this share has increased steadily from only 0.44 percent in 1997, as successive governments have injected more money into the granting councils.

Table 1
HERD\(^1\) as a Percentage of GDP, Selected OECD Countries, 2004

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<th>Country</th>
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</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>0.87</td>
</tr>
<tr>
<td>Canada</td>
<td>0.70</td>
</tr>
<tr>
<td>Finland</td>
<td>0.68</td>
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<tr>
<td>Switzerland</td>
<td>0.64</td>
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<td>Denmark</td>
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<tr>
<td>Austria</td>
<td>0.59</td>
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<tr>
<td>The Netherlands</td>
<td>0.50</td>
</tr>
<tr>
<td>Australia</td>
<td>0.48</td>
</tr>
<tr>
<td>Norway</td>
<td>0.48</td>
</tr>
<tr>
<td>Japan</td>
<td>0.43</td>
</tr>
<tr>
<td>Germany</td>
<td>0.41</td>
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<tr>
<td>France</td>
<td>0.41</td>
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<tr>
<td>Belgium</td>
<td>0.41</td>
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<tr>
<td>United Kingdom</td>
<td>0.40</td>
</tr>
<tr>
<td>United States</td>
<td>0.36</td>
</tr>
<tr>
<td>Italy</td>
<td>0.36</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.33</td>
</tr>
<tr>
<td>Korea</td>
<td>0.29</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>0.19</td>
</tr>
<tr>
<td>Total OECD</td>
<td>0.39</td>
</tr>
</tbody>
</table>

\(^1\) Higher education expenditure on R&D.
is transferred to industry through the knowledge and training of NS&E graduates, Canada appears to be competitive internationally.

Canada also scores reasonably well in terms of scholarly publications per capita. In fact, it is eighth in the world on this indicator, ahead of the United States, Germany and France, but below Switzerland, Sweden and other Nordic nations (table 4). Publications are widely considered one of the most important channels of technology transfer, and here again Canada appears to perform respectably.

Finally, in the area of university spinoffs (a more direct indicator of commercially useful academic research), Canada lags behind the United States, which is often considered a model in terms of new firms founded on the basis of academic research. In its most recent survey of technology licensing, the Association of University Technology Managers (AUTM) reported that the 189 US universities that responded to their survey had launched 628 startups in 2005, an average of 3.3 startups per university (AUTM 2007a). In the comparable Canadian survey, the 34 universities that responded reported just 36 startup companies (AUTM 2007b).3

University spinoffs are highly concentrated in technical services fields. Forty-one percent of university spinoffs were in the scientific R&D services industry—most often related to biotechnology—and computer systems design. In terms of manufacturing, the most frequently reported spinoffs were in measuring, medical and controlling devices and medical equipment and supplies manufacturing, but taken together these account for under 5 percent of spinoffs (table 5).

This concentration is consistent with the evidence from other OECD nations: in the last 20 years these

<table>
<thead>
<tr>
<th>Country</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td>15.9</td>
</tr>
<tr>
<td>Germany</td>
<td>13.2</td>
</tr>
<tr>
<td>Belgium</td>
<td>11.6</td>
</tr>
<tr>
<td>Switzerland</td>
<td>8.7</td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td><strong>8.2</strong></td>
</tr>
<tr>
<td>The Netherlands</td>
<td>6.8</td>
</tr>
<tr>
<td>Finland</td>
<td>5.8</td>
</tr>
<tr>
<td>Australia</td>
<td>5.7</td>
</tr>
<tr>
<td>Sweden</td>
<td>5.5</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5.1</td>
</tr>
<tr>
<td>United States</td>
<td>5.0</td>
</tr>
<tr>
<td>Norway</td>
<td>5.0</td>
</tr>
<tr>
<td>Austria</td>
<td>4.5</td>
</tr>
<tr>
<td>Denmark</td>
<td>3.0</td>
</tr>
<tr>
<td>Japan</td>
<td>2.8</td>
</tr>
<tr>
<td>France</td>
<td>2.7</td>
</tr>
<tr>
<td>Ireland</td>
<td>2.6</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>0.6</td>
</tr>
<tr>
<td>Total OECD</td>
<td>6.1</td>
</tr>
</tbody>
</table>


Table 2
Proportion of HERD1 Funded by Business, Selected OECD Countries, 2004

<table>
<thead>
<tr>
<th>Country</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td>15.9</td>
</tr>
<tr>
<td>Germany</td>
<td>13.2</td>
</tr>
<tr>
<td>Belgium</td>
<td>11.6</td>
</tr>
<tr>
<td>Switzerland</td>
<td>8.7</td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td><strong>8.2</strong></td>
</tr>
<tr>
<td>The Netherlands</td>
<td>6.8</td>
</tr>
<tr>
<td>Finland</td>
<td>5.8</td>
</tr>
<tr>
<td>Australia</td>
<td>5.7</td>
</tr>
<tr>
<td>Sweden</td>
<td>5.5</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5.1</td>
</tr>
<tr>
<td>United States</td>
<td>5.0</td>
</tr>
<tr>
<td>Norway</td>
<td>5.0</td>
</tr>
<tr>
<td>Austria</td>
<td>4.5</td>
</tr>
<tr>
<td>Denmark</td>
<td>3.0</td>
</tr>
<tr>
<td>Japan</td>
<td>2.8</td>
</tr>
<tr>
<td>France</td>
<td>2.7</td>
</tr>
<tr>
<td>Ireland</td>
<td>2.6</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>0.6</td>
</tr>
<tr>
<td>Total OECD</td>
<td>6.1</td>
</tr>
</tbody>
</table>


financial stake in university-performed research would indicate that technology transfer channels are well developed, but as I will show later, in Canada this is not necessarily the case.

Canada has a fairly high ratio of university graduates in natural sciences and engineering (NS&E). There were 7.1 bachelor’s NS&E degrees awarded in Canada per 100 24-year-olds, more than in the United States and the sixth-highest among major industrialized nations (table 3).2 However, NS&E degrees account for only 23.8 percent of total degrees awarded in Canada. By this metric, Canada’s ranking falls to ninth. To the extent that technology

<table>
<thead>
<tr>
<th>Country</th>
<th>Degrees awarded per 100 24-year olds (N)</th>
<th>All fields</th>
<th>NS&amp;E fields</th>
<th>NS&amp;E degrees as a % of all degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>41.9</td>
<td>11.4</td>
<td>27.2</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>35.7</td>
<td>10.2</td>
<td>25.8</td>
<td></td>
</tr>
<tr>
<td>United Kingdom (2003)</td>
<td>39.7</td>
<td>8.4</td>
<td>21.3</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>32.1</td>
<td>7.8</td>
<td>24.4</td>
<td></td>
</tr>
<tr>
<td>Japan (2004)</td>
<td>32.0</td>
<td>7.1</td>
<td>23.8</td>
<td></td>
</tr>
<tr>
<td><strong>Canada (2001)</strong></td>
<td><strong>29.9</strong></td>
<td><strong>7.1</strong></td>
<td><strong>23.8</strong></td>
<td></td>
</tr>
<tr>
<td>The Netherlands</td>
<td>38.9</td>
<td>7.1</td>
<td>18.2</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>25.0</td>
<td>6.7</td>
<td>26.9</td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>22.9</td>
<td>6.0</td>
<td>26.3</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>20.8</td>
<td>5.7</td>
<td>27.7</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>33.9</td>
<td>5.7</td>
<td>16.8</td>
<td></td>
</tr>
</tbody>
</table>

nations have witnessed a surge in the number of university patents, licences, academic spinoffs, and university-industry research corporations and collaboration, but this surge was generally concentrated in biotechnology, information technologies, and materials (Mowery et al. 2001).

It is important to emphasize the fact that the vast majority of Canadian university technology comes from the largest research universities (table 6). These 25 institutions (defined as those with at least $80 million worth of sponsored research annually) account for 85 percent of all university inventions, over 90 percent of patents granted to universities, 95 percent of intellectual property royalties and 78 percent of spinoff companies. The relative concentration of university-developed technologies reduces the number of relationships that businesses must develop to access academic knowledge. At the same time, these elite institutions are located in 16 different census metropolitan areas, so the supply of university-developed technologies is well distributed across Canada.

Yet, in spite of its outstanding performance along many of these supply-side dimensions, Canada is host to a surprisingly low number of large high-technology and science-based companies. For instance, on the 2006 Fortune Global 500 list of the world’s largest corporations, only 13 are Canadian and of these only 3 are technology-intensive: Bombardier, Magna and Nortel. In Canada, many high-technology companies are created, but few of them reach a large size. This dampens the demand for university technology through all its channels.

Also, Canadian productivity has lagged in recent years, compared with both that in the past and that of the United States. In the 2000s, US productivity growth has accelerated relative to the 1990s to reach an average of 2.9 percent per year, while Canadian productivity growth decelerated sharply to just 1 percent annually. As a result, Canadian productivity levels (measured as GDP per hour worked) slipped from the 82-to-84-percent range in the 1990s to 74 percent by 2006 (Centre for the Study of Living Standards 2007). Large firms are much more productive than small ones (Gu and Tang 2004; Lee and Tang 2001), and Canada has a disproportionately high proportion of small firms. Thus, in spite of Canada’s high rank in the raw quantity of academic research, there is ample room for improvement with regard to its contribution to better business productivity and innovative products.

It is clear from the above that the supply side of academic research is reasonably healthy, particularly with regard to the financial resources devoted to university research. This is not surprising, because historically the policy and research focus has been almost exclusively on promoting and funding basic academic and government research. What is less healthy is the efficacy with which university-generated knowledge reaches the demand side — whether due to inadequate demand, bottlenecks in technology transfer or mismatches in supply and demand.

### Table 4

<table>
<thead>
<tr>
<th>Country</th>
<th>Total</th>
<th>Per million people</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switzerland</td>
<td>8,542</td>
<td>1,170</td>
</tr>
<tr>
<td>Sweden</td>
<td>10,237</td>
<td>1,150</td>
</tr>
<tr>
<td>Finland</td>
<td>5,202</td>
<td>1,000</td>
</tr>
<tr>
<td>Denmark</td>
<td>5,291</td>
<td>980</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>13,475</td>
<td>842</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>48,288</td>
<td>805</td>
</tr>
<tr>
<td>Australia</td>
<td>15,809</td>
<td>790</td>
</tr>
<tr>
<td>Canada</td>
<td>24,803</td>
<td>775</td>
</tr>
<tr>
<td>Norway</td>
<td>3,339</td>
<td>742</td>
</tr>
<tr>
<td>United States</td>
<td>211,236</td>
<td>728</td>
</tr>
<tr>
<td>Belgium</td>
<td>6,604</td>
<td>647</td>
</tr>
<tr>
<td>Austria</td>
<td>4,906</td>
<td>598</td>
</tr>
<tr>
<td>Germany</td>
<td>44,305</td>
<td>538</td>
</tr>
<tr>
<td>France</td>
<td>31,971</td>
<td>533</td>
</tr>
<tr>
<td>Japan</td>
<td>60,069</td>
<td>473</td>
</tr>
<tr>
<td>Ireland</td>
<td>1,758</td>
<td>451</td>
</tr>
<tr>
<td>Italy</td>
<td>24,696</td>
<td>426</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>2,950</td>
<td>295</td>
</tr>
<tr>
<td>Korea</td>
<td>13,746</td>
<td>286</td>
</tr>
</tbody>
</table>


### Table 5

<table>
<thead>
<tr>
<th>NAICS industry</th>
<th>Spinoffs</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D in the physical, engineering and life sciences</td>
<td>240</td>
<td>27.4</td>
</tr>
<tr>
<td>Computer system design and related services</td>
<td>119</td>
<td>13.6</td>
</tr>
<tr>
<td>Management, scientific and technical consulting services</td>
<td>39</td>
<td>4.4</td>
</tr>
<tr>
<td>Professional engineers</td>
<td>33</td>
<td>3.8</td>
</tr>
<tr>
<td>Measuring, medical and controlling devices manufacturing</td>
<td>27</td>
<td>3.1</td>
</tr>
<tr>
<td>Testing laboratories</td>
<td>16</td>
<td>1.8</td>
</tr>
<tr>
<td>Medical equipment and supplies manufacturing</td>
<td>11</td>
<td>1.3</td>
</tr>
<tr>
<td>Other reported industry groups</td>
<td>168</td>
<td>19.2</td>
</tr>
<tr>
<td>Industry groups not reported</td>
<td>223</td>
<td>25.4</td>
</tr>
<tr>
<td>Total spinoffs</td>
<td>876</td>
<td>100.0</td>
</tr>
</tbody>
</table>


1 North American Industry Classification System.
Table 6
Commercialization of Intellectual Property in Universities, by Institution Size, Canada, 2004

<table>
<thead>
<tr>
<th>Size of university (value of sponsored research)</th>
<th>Institutions</th>
<th>Total sponsored research ($ millions)</th>
<th>Inventions</th>
<th>Patents</th>
<th>Licences and options executed</th>
<th>Income from IP ($ millions)</th>
<th>Spinoff companies created to date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (&lt;$25 million)</td>
<td>80</td>
<td>252</td>
<td>43</td>
<td>25</td>
<td>8</td>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td>Medium ($25-$79 million)</td>
<td>14</td>
<td>555</td>
<td>172</td>
<td>75</td>
<td>36</td>
<td>30</td>
<td>1.5</td>
</tr>
<tr>
<td>Large ($80 million or more)</td>
<td>25</td>
<td>4,239</td>
<td>1,217</td>
<td>528</td>
<td>353</td>
<td>454</td>
<td>49.2</td>
</tr>
<tr>
<td>Total</td>
<td>119</td>
<td>5,046</td>
<td>1,432</td>
<td>629</td>
<td>397</td>
<td>494</td>
<td>51.2</td>
</tr>
</tbody>
</table>


Table 7
BERD\(^1\) as a Proportion of GDP, Selected OECD Countries, 2004

<table>
<thead>
<tr>
<th>Country</th>
<th>% of GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>2.73</td>
</tr>
<tr>
<td>Finland</td>
<td>2.42</td>
</tr>
<tr>
<td>Japan</td>
<td>2.36</td>
</tr>
<tr>
<td>Korea</td>
<td>2.18</td>
</tr>
<tr>
<td>Switzerland</td>
<td>2.16</td>
</tr>
<tr>
<td>United States</td>
<td>1.88</td>
</tr>
<tr>
<td>Germany</td>
<td>1.75</td>
</tr>
<tr>
<td>Denmark</td>
<td>1.69</td>
</tr>
<tr>
<td>Austria</td>
<td>1.51</td>
</tr>
<tr>
<td>France</td>
<td>1.34</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.29</td>
</tr>
<tr>
<td>Canada</td>
<td>1.12</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1.09</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>1.03</td>
</tr>
<tr>
<td>Australia</td>
<td>0.95</td>
</tr>
<tr>
<td>Norway</td>
<td>0.89</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.82</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>0.80</td>
</tr>
<tr>
<td>Italy</td>
<td>0.53</td>
</tr>
<tr>
<td>All OECD countries</td>
<td>1.53</td>
</tr>
</tbody>
</table>


1 Business expenditures on R&D.

Demand for University Technology

Some demand factors have been closely studied. Canada’s domestic market is relatively small compared with those of its major competitors, such as the United States, the European Union, Japan and, more recently, China. Its domestic market is scattered over 27 metropolitan areas in a very large territory, which affects transportation and communication costs, as well as the transmission of knowledge externalities among universities, public laboratories and business. These universities are located in such places as Halifax, Montreal, Ottawa, Toronto, Edmonton, Calgary, Vancouver, and Victoria. This large geographical spread has advantages — each large city has at least one university — and disadvantages — cooperation among universities is difficult.

Because industry is the main user of university-developed technology, countries with high levels of business expenditures on R&D (BERD) should experience stronger demand for university technology than those with lower BERD intensity. Canada’s BERD intensity is relatively low compared with those of the largest OECD countries, and is lower than the OECD average (table 7), suggesting that industrial demand for academic knowledge in Canada is lower than it is in Canada’s main competitors, including the United States, Japan, Germany and France. Canada hosts many resource-intensive industries whose firms have low or medium R&D intensity, and this is one of the reasons for Canada’s poor aggregate performance.

However, ab Iorwerth (2005) compared the R&D intensity in specific industries in Canada and the United States and concluded that Canada’s lower BERD intensity is due mainly to lower R&D intensity in selected large industries (particularly automobile manufacturing and the service sector) as opposed to differences in industrial structure. Furthermore, key high-technology industries in Canada (such as pharmaceutical products and electronic equipment), while smaller in relative terms than their counterparts in the US, actually have higher R&D intensity. Contrary to conventional wisdom, there appear to be pockets of strength in potential demand for university-developed technologies.

In a much-cited article, Cohen and Levinthal (1990) argued that firms’ ability to recognize the value of external information and apply it to commercial production depends on their absorptive capacity. Human capital is the base of absorptive capacity, and it is unevenly distributed among firms (Zahra and George 2002). In Canada, human capital is concentrated in pharmaceutical, computer and electrical equipment and appliances, chemicals and petroleum and coal products...
only three Canadian companies are among the world’s largest technology firms.

Perhaps most important, universities are not the only source of technology for companies. In fact, for Canadian firms, other domestic and foreign companies are a much more important source of technology than universities (table 10). The greatest users of licensed technology were the pharmaceuticals, computers and electronic products, petroleum and coal products, and transportation equipment (aerospace) industries. While companies in some industries (such as pharmaceuticals and primary metals manufacturing) do acquire technology from universities, they are far more likely to acquire it from other firms.

Surprisingly, the aerospace industry — which relies heavily on constant technology improvement — does not draw on universities at all for technology licensing. Aerospace companies in Canada conduct surprisingly little R&D and own few patents compared with their US and European competitors, thus reducing demand for university technology (Zheng 2007).

Finally, innovation is more frequent in larger firms, and the tendency to collaborate with universities increases with the size of the firm (Hanel and St-Pierre 2006). Most industry-university collaborations involve firms of over 500 employees.

The evidence on the robustness of university technology demand is thus mixed. Canada’s poor performance with regard to BERD has long been documented and lamented, but there are pockets of strength in high-tech industries such as pharmaceuticals and electronic products. At the same time, most Canadian firms turn to other companies for licensed technology — circumstantial evidence that they are not finding the technologies they need in universities.

Table 8
Full-Time Employees with Post-Secondary Education in Innovative Manufacturing Plants, by Industrial Sector, Canada, 2005

<table>
<thead>
<tr>
<th>Industry</th>
<th>% of employees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>University degree</td>
</tr>
<tr>
<td>Logging</td>
<td>n.a.</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>9.8</td>
</tr>
<tr>
<td>Food, beverages, and tobacco</td>
<td>9.8</td>
</tr>
<tr>
<td>Textiles</td>
<td>7.4</td>
</tr>
<tr>
<td>Clothing and leather products</td>
<td>7.7</td>
</tr>
<tr>
<td>Wood product manufacturing</td>
<td>4.2</td>
</tr>
<tr>
<td>Paper manufacturing</td>
<td>7.4</td>
</tr>
<tr>
<td>Printing and related activities</td>
<td>7.9</td>
</tr>
<tr>
<td>Petroleum and coal products</td>
<td>15.7</td>
</tr>
<tr>
<td>Chemical manufacturing</td>
<td>19.2</td>
</tr>
<tr>
<td>Chemicals (excl. pharmaceuticals)</td>
<td>15.8</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>37.2</td>
</tr>
<tr>
<td>Plastics and rubber manufacturing</td>
<td>7.5</td>
</tr>
<tr>
<td>Nonmetallic mineral products</td>
<td>7.0</td>
</tr>
<tr>
<td>Primary metal manufacturing</td>
<td>8.0</td>
</tr>
<tr>
<td>Fabricated metal manufacturing</td>
<td>6.1</td>
</tr>
<tr>
<td>Machinery manufacturing</td>
<td>9.4</td>
</tr>
<tr>
<td>Computer and electronic products</td>
<td>30.1</td>
</tr>
<tr>
<td>Electrical equipment, appliances</td>
<td>14.7</td>
</tr>
<tr>
<td>Transportation equipment</td>
<td>9.6</td>
</tr>
<tr>
<td>Furniture and related manufacturing</td>
<td>6.2</td>
</tr>
<tr>
<td>Miscellaneous manufacturing</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Note: Innovative plants are those that have made at least one innovation in the two years preceding the survey.

Table 9
Business Expenditures on R&D, Selected Industries, Canada, 2006

<table>
<thead>
<tr>
<th>Industry</th>
<th>Millions of dollars</th>
<th>Percent of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications equipment</td>
<td>1,634</td>
<td>11</td>
</tr>
<tr>
<td>Information and cultural industries</td>
<td>1,485</td>
<td>10</td>
</tr>
<tr>
<td>Pharmaceuticals and medicine</td>
<td>1,337</td>
<td>9</td>
</tr>
<tr>
<td>Scientific R&amp;D</td>
<td>1,188</td>
<td>8</td>
</tr>
<tr>
<td>Computer systems design and services</td>
<td>1,040</td>
<td>7</td>
</tr>
<tr>
<td>Aerospace products and parts</td>
<td>891</td>
<td>6</td>
</tr>
<tr>
<td>Semiconductor and other electronic components</td>
<td>891</td>
<td>6</td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>743</td>
<td>5</td>
</tr>
<tr>
<td>Other industries</td>
<td>5,643</td>
<td>38</td>
</tr>
<tr>
<td>Total expenditures, all industries</td>
<td>14,850</td>
<td>100</td>
</tr>
</tbody>
</table>

The fact that universities play such a marginal role in technology licensing in Canada demands a closer look at the mechanics of university-industry technology transfer.

In most Canadian universities, academic researchers must disclose all inventions they develop or discover that may have commercial potential to the university's office of technology transfer (OTT) or university-industry liaison office (UILO). The OTT/UILO then evaluates it and decides whether the invention should be protected through patents, copyright (in the case of software), industrial design or other intellectual property legislation. If the OTT/UILO decides protection is needed, the inventor and the university then sign an agreement about the division of the eventual royalties. The OTT/UILO then proceeds to look for potential licensees. If it decides that the invention is not worth protecting, full rights of commercialization are returned to the inventor, who then has entire freedom to commercialize it.

A major difference between the US and Canada is that in the US, university-produced innovations belong exclusively to the university, while in Canada each university has its own rules. There is a trend in Canada toward compulsory disclosure and eventual retrocession of the innovation to the inventor, who could patent or offer the technology to a company. In less than half of Canada's universities, inventions must always be reported (table 11).

The innovation, whether owned by the academic or by the university, can be licensed to a private company, large or small. In many cases, however, the innovation is produced by the academic under contract with a firm, with the condition that the invention will belong to that firm, and cannot be disclosed or become property of the university.

Under this system, the entire responsibility of locating a potential user of any given innovation falls upon either the OTT/UILO or the researcher — essentially a
supply-push model. Yet, evidence suggests that neither is entirely equipped to assess the commercial value of the technology or its potential market. In Canada, the European Union and the US, a large percentage of the patents where academics are the inventors belong to private firms or to the researchers themselves. In several cases, these discoveries were returned to the inventors by the academic institutions. Most OTTs/UILOs are staffed by just a handful of individuals, who simply cannot be expected to stay on top of all potential markets for the inventions that come across their desks. I will suggest later that increasing the demand for university technology, particularly among SMEs, through incentives to seek out university-developed research — a demand-pull model — is a far better way to promote academic technology commercialization. These incentives may substantially help address bottlenecks, match suppliers with demanders and move more university-developed technologies across the valley of death.

**Legislative changes: a Canadian Bayh-Dole Act?**

In the United States, the *Bayh-Dole Act* of 1980 represents a landmark in terms of legislative efforts to stimulate the transfer of university-developed technology to industry. It was motivated by the fact that the US government held tens of thousands of patents stemming from its funding of R&D in universities and government laboratories. However, only a tiny proportion of these were commercially licensed, reflecting the fact that governments are not primarily in the business of technology commercialization.

To increase the incentive to commercialize publicly funded R&D, the Act transfers ownership of an invention or discovery from the government agency that helped to pay for it to the academic institution that carried out the actual research. Furthermore, it ensures that the researchers themselves receive a portion of the economic benefits resulting from it. Over the course of time, other jurisdictions have adopted similar legislation; for example, Germany passed such legislation in 2001 and, in Canada, Quebec passed a similar law in 2002.

Evidence on the effectiveness of the *Bayh-Dole Act* is mixed. The Expert Panel on Commercialization concluded that it was directly responsible for the creation of thousands of new firms and added tens of billions of dollars to the US economy (2006). But an earlier study of Stanford, MIT and Columbia found very little change in these universities’ patent and licensing portfolios in the 10 years following the passage of the *Bayh-Dole Act*, and concluded that the Act had little, if any, effect on technology transfer (Mowery et al. 2001).

Irrespective of the magnitude of economic benefits from the *Bayh-Dole Act* and similar legislation, there is concern in some quarters that the incentives they contain encourage undue commercial influence on the direction of academic research. Many scientists, economists and lawyers believe such incentives distort the fundamental mission of universities, diverting them from the pursuit of basic knowledge, which is freely disseminated, to a focused search for results that have practical and industrial purposes.

Finally, according to the AUTM surveys, American and Canadian university academic publication rates are similar, controlling for the size of the two countries and the research funds available to academics in the two nations (AUTM 2007a,b). At the same time, wide differences persist among universities in the two countries’ ability to patent, license and create spin-off companies (table 12). It may be that the differ-

### Table 11

<table>
<thead>
<tr>
<th>Reporting of Intellectual Property (IP) at Canadian Universities (Number of Universities)</th>
<th>Obliged to report IP?</th>
<th>No policy on reporting</th>
<th>No such IP at the institution</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Always</td>
<td>Sometimes</td>
<td>Never</td>
<td></td>
</tr>
<tr>
<td>Inventions</td>
<td>49</td>
<td>23</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>IP protected by copyright</td>
<td>31</td>
<td>36</td>
<td>9</td>
<td>32</td>
</tr>
<tr>
<td>Software</td>
<td>25</td>
<td>36</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>Education materials</td>
<td>24</td>
<td>35</td>
<td>13</td>
<td>41</td>
</tr>
<tr>
<td>Other materials</td>
<td>32</td>
<td>17</td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td>Industrial designs</td>
<td>31</td>
<td>17</td>
<td>7</td>
<td>34</td>
</tr>
<tr>
<td>Trademarks</td>
<td>18</td>
<td>15</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>New plant varieties</td>
<td>31</td>
<td>36</td>
<td>9</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>15</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>

Source: Read (2006, table 8).
ences in the experience and the quality of their OTT/UILO personnel, organizational structures, and financial resources, as well as differences in university cultures, explain some of the wide variations among universities (Rothaermel, Agung and Jiang 2007). Lotka’s Law may also explain the wide variations: over 60 percent of academic publishing is accounted for by less than 6 percent of academics. It may be that the same law applies to university patenting. Some universities have been able to attract highly productive and entrepreneurial academics who make a difference in the institutions.5

It may be that the rapid increase academic patenting and licensing in both countries since 1990 is due not to the legislative environment, but to the rise of biotechnology, a discipline that reinforces pharmaceutical research and is responsible for over 50 percent of all patents, licences, income and spinoff companies in the two countries (Mowery et al. 2001).

When analyzing the supply of university technology, one has to bear in mind that in Canada the majority of the patents stemming from academic research in the top universities are assigned not to the university but to private firms (Gingras et al. 2004). The figures are similar in Europe (Crespi, Geuna and Verspagen 2006; Geuna and Nesta 2006; Saragossi and van Pottelsberghe de la Potterie 2003). In sharp contrast, over 62 percent of the patents invented by faculty members at the top US research universities were assigned to the institutions, and only 26 percent solely to firms. These figures are important because they show that some technology transfer goes unnoticed because attention is focused on technology owned by universities and transferred to industries, ignoring the sub-

Table 12
Number of Licences, Patents, Publications and Spinoffs Acquired by Universities, Canada and the US

<table>
<thead>
<tr>
<th></th>
<th>Canada</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of universities responding</td>
<td>36</td>
<td>158</td>
</tr>
<tr>
<td>Patent applications (2005)</td>
<td>685</td>
<td>15,115</td>
</tr>
<tr>
<td>Patent application per university</td>
<td>19</td>
<td>96</td>
</tr>
<tr>
<td>Licences (2005)</td>
<td>503</td>
<td>4,201</td>
</tr>
<tr>
<td>Licences per university</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>New spinoffs</td>
<td>36</td>
<td>586</td>
</tr>
<tr>
<td>New spinoffs per university</td>
<td>1</td>
<td>3.7</td>
</tr>
<tr>
<td>Science and engineering articles (2005)</td>
<td>25,836</td>
<td>205,320</td>
</tr>
<tr>
<td>Science and engineering articles per million population (2005)</td>
<td>783</td>
<td>684</td>
</tr>
</tbody>
</table>

Sources: Patents, licences and spinoffs: AUTM (2007c, d); science and engineering articles: National Science Foundation (2006).

According to Thursby, Fuller and Thursby (2007), patents in the physical and engineering sciences were more often assigned to firms, while those in the biological sciences were more likely to be assigned to universities. Another, similar, study found that 33 percent of the university-invented patents were assigned to firms (Markman, Gianodis and Phan 2006). In both cases, Bayh-Dole and university regulations were bypassed. This is due to the fact that most academic research that results in patents is supported by contract research, not by public funds, and the inventors assign the research results to their sponsors, not to their universities.

Since most university research in Canada is not patented and licensed by universities, the incentives in Bayh-Dole-type legislation would not capture some key channels of technology transfer from universities to industry. The creators of Bayh-Dole could not have foreseen all the possible channels of technology transfer, such as technologies that universities do not patent but that nevertheless attract business enterprises, mostly large ones. Canadian surveys of innovation show that large companies have many more links with universities than do small companies. Yet, there are more than a million small companies in Canada. Increases in Canadian productivity is more likely to come from smaller companies than from larger ones (Terajima, Leung and Marsh 2006).

Despite the fact that there are many influential proponents of Canada adopting the equivalent of the Bayh-Dole Act (including the 1999 report of the Advisory Council on Canadian Science and Technology), it would be unwise to do so. The economic benefits of such legislation would likely be very small, and it would have virtually no effect on the large amount of academic research that is contracted directly by industry.

Moving toward a demand-pull model of university-industry technology transfer
The fundamental challenge of crossing the valley of death is that it is exceedingly difficult to coordinate the myriad research activities in universities with the ever-changing technology needs of industry (and, as noted above, excessive coordination may not be desirable). Thousands of academic papers are published annually in
hundreds of journals and conference proceedings, and it is beyond the capacity of even the best-equipped university OTI/UILO to identify which inventions are most likely to have commercial potential.

A more promising option is to turn the equation around: businesses are much better equipped to judge the commercial potential of university research, but they are unwilling to shoulder the financial risk of carrying it out. This is particularly true of SMEs. The social benefits of encouraging businesses to do so are potentially large and would justify government support.

The United States has been innovative compared with other countries in this regard. In 1982, the United States passed the Small Business Innovation Research Act (SBIR) in order to facilitate the absorption of new technology by small and medium-sized enterprises, and in 1992 it passed the Small Business Technology Transfer Research Act (STTR). The SBIR provides up to $850,000 in early-stage R&D to small technology companies or to entrepreneurs who launch a company. The STTR program provides up to a similar sum to small companies working in cooperation with academic researchers at universities or government researchers in public laboratories, in order to explore the commercial feasibility of new ideas emerging from these institutions. The different federal departments that allocate R&D funds to private firms, the most important of which is the Department of Defense, run both programs. In fiscal year 2007, all departments combined, SBIR was funded at US$1.14 billion and STTR at $131 million. In order to qualify for SBIR grants, firms must have fewer than 500 employees and conduct R&D in the United States. In addition, the principal investigator has to work at least half time in the proposing firm. The STTR grants have similar firm-size requirements, but the principal investigator may be employed at either the firm or the research institution. Also, the SME has to be more than 50 percent owned by its managers and/or employees. This prerequisite creates obstacles for companies already financed by venture capital, but has the advantage of concentrating funds in the early stages of technology development. Thus, SBIR and STTR appear as second- to third-stage funds (see figure 1). The programs have three phases (table 13). Small businesses compete in phase I, and at this stage the grant is allocated after peer review of the technology. If phase I achieves promising results, then a second grant is awarded to the firm. Phase III is the commercialization stage, where no SBIR funds are committed. Phase II finishers are supposed to obtain either private or other public funds to continue the R&D process. Also, in fiscal year 2006, over 90 percent of the awardees were firms with fewer than 100 employees (see figure 2). This means that the program, which is aimed at small firms, is reaching its intended target.

SBIR and STTR programs have helped thousands of innovative firms to explore the technical merit of new ideas or technologies, which typically emerge from academic or public laboratory research, by reducing the cost of exploration and conversion of scientific ideas into commercial products (Auerswald and Branscomb 2003; Wessner 1999). An evaluation of SBIR conducted in 2006, while criticizing some of its management routines (and suggesting ways the program could be improved), concluded that it was attaining most of its specific missions (RAND Corporation 2006).

Another American initiative is the Advanced Technology Program (ATP). In 1990, the US Congress created ATP in the US National Institute of Standards and Technology (NIST), part of the Department of Commerce, in order to help US businesses commercialize generic technologies and refine manufacturing methods. Companies, or consortia of companies, propose research projects to NIST, and the agency selects the proposals considered to have the largest economic potential. Government and industry share the costs of early-stage technology development. Universities can participate in consortia and propose projects but, significantly, they cannot serve as project leaders.

ATP is more of a demand-pull program with regard to early-stage technologies: the research priorities in funded projects are set by industry, not by the government, academia or public laboratories. Partner companies must pay at least 50 percent of the project costs. ATP funding eligibility is not confined to SMEs; large corporations may also participate, but they must cover

<table>
<thead>
<tr>
<th>Table 13</th>
<th>Summary of US Small Business Innovation Research Act (SBIR) and Small Business Technology Transfer Act (STTR) Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>SBIR</td>
</tr>
<tr>
<td>Phase I</td>
<td>Project feasibility</td>
</tr>
<tr>
<td>Phase II</td>
<td>Project development to prototype</td>
</tr>
<tr>
<td>Phase III</td>
<td>Commercialization</td>
</tr>
</tbody>
</table>

Source: Calculations by author based on information from www.zyn.com/sbir
US venture capital does, and it encourages the proliferation of very small enterprises. Consider the situation of biotechnology, the industry that receives the majority of technologies transferred from universities. In 2005, Canada had over 500 dedicated biotechnology firms (DBFs). This compared with 1,500 in the United States, which has an economy over 10 times larger than Canada’s. Canadian DBFs often live or die with one technology. Introduced in Canada, programs like the American ones described here might serve to consolidate smaller firms into larger and more viable entities.

Policy Options for Canada

Mohnen and Röller (2005) have shown that innovation policies often complement each other: some reinforce the supply of human capital and the production of technology, while others nurture the adoption of technology and the demand for human capital. From the foregoing analysis, it is clear that Canada has much room for improvement in terms of stimulating the demand for university technology. The Industrial Research Assistance Program (IRAP), under the auspices of the National Research Council, is the main vehicle for supporting SME business innovation. IRAP provides four main services: advice, financial support for R&D activities, networking and partnerships. Its total annual budget is about $150 million, of which just under 50 percent is earmarked for R&D activities. IRAP is generally well regarded, and displays some characteristics of demand-pull technology transfer. It has been evaluated several times and has always obtained high marks (Lipsey and Carlaw 1998). In a study that compared the effectiveness of IRAP and venture capital in stimulating university spinoffs, Niosi (2006) found that IRAP funding was more often linked to rapid growth than is private venture capital. Its funding should be increased.

The SME Partnerships Initiative, proposed by the Expert Panel on Commercialization, would be a commercialization superfund to address SMEs’ commercialization challenges, to expand federal programs that support seed and start-up firms in proving their business ideas, and to increase research funds to SMEs to augment and improve technology transfer to smaller firms. It would differ from the STTR/SBIR programs in one critical respect. Under the American programs, the firms themselves undertake initiatives and applications, and decide which technologies deserve further exploration. Under the proposed SME

![Diagram](https://via.placeholder.com/150)

**Figure 2**
Size Distribution of Firms Receiving Funding through the Small Business Innovation Research Act and Small Business Technology Transfer Act, United States, 2006

at least 60 percent of the costs of the project. The program does not cover product development. Also, like SBIR and STTR, it is not a substitute for tax credits for R&D or venture capital; but smaller companies often do not have any taxable income to benefit from tax credits. Thus, ATP helps emerging companies to explore new technologies in partnership with academic or government researchers. Out of 768 ATP awards granted between 1990 and September 2004, 508 (66 percent) went to small businesses, either as single applicants or leading joint ventures. In this period, ATP committed US$2.2 billion, and private companies committed a similar amount, for an average award of $3 million and 55 awards per year.7

In its 2001 report, the US National Research Council concluded that ATP is a successful program for bringing early-stage technologies to commercial fruition. The council suggested several operational improvements, such as reducing the delays between applications and awards, concentrating on selected areas of science and technology and stabilizing R&D funding (Wessner and STEP 2001).

Programs such as these are an interesting solution to the technology transfer conundrum: a bridge over the valley of death. They can also provide some support to help small firms grow. While it is true that Canada has one of the highest ratios of venture capital to GDP (Baygan 2003), that venture capital is concentrated in the early stages of funding (seed capital). Thus it is spread more thinly and supports more companies than

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7 Source: Calculations by the author based on information from www.zyn.com/sbir

Connecting the Dots between University Research and Industrial Innovation, by Jorge Niosi
have helped thousands of innovative SMEs to explore the technical merit of a new idea or technology, typically one emerging from academia or a public laboratory (Auerswald and Branscomb, 2003; Wessner, 1999). Some demand-side policies would thus help increase the absorptive capacity of high-technology industries, which in Canada mostly consist of small firms.

Canada does not need Bayh-Dole-type legislation. It is far from certain that the Bayh-Dole Act has improved the performance of university-industry linkages in the United States. If the US academic system performs on average better than those of other countries, this may be due to a combination of internal and external factors, including high levels of public funding for academic research, a system based on global recruitment of professors and students, a very active venture capital industry supporting university start-ups, large internal national and regional markets, and policies stimulating the exploration of public technologies by SMEs. Also, legislating patents, spinoffs and licences would only affect a few of the numerous channels of university-industry technology transfer, without even eliminating the assignment of intellectual property generated by academics to their industrial partners through contractual research and IP protection of all the inventions disclosed by academics.

Conclusions

For a more balanced national system of innovation, policy-makers in Canada should focus on demand-pull policies that encourage businesses to participate more directly in research funding decisions that impinge on university research directions, without going so far as to dictate their specifics. This would be the most effective way to support the commercialization process. University professors are primarily motivated by the attraction of publishing, but knowing that businesses are interested in what goes on in their labs may influence the broad research directions they take, without compromising the integrity and independence of individual projects.

Demand-pull policies are much better developed in the United States than they are in Canada. Although they would be costly to fund and complex to implement in Canada, programs like ATP, SBIR and STTR could increase demand among SMEs for academic and government laboratory technology. These programs...
### Appendix 1

**Channels of Technology Transfer between Academic Institutions and Industry**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Specific forms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Publication</td>
<td>Industry consulting scientific publication; co-publications between academics and industry</td>
</tr>
<tr>
<td>Participation in professional networks</td>
<td>Participation in conferences and fairs; exchanges in professional organizations; industry participation in university boards</td>
</tr>
<tr>
<td>Mobility of people</td>
<td>Graduates; mobility of academics to industry; mobility of industrial researchers to universities; trainees; double appointments; temporary exchange of personnel</td>
</tr>
<tr>
<td>Other informal networks</td>
<td>Networks based on friendship; alumni societies; other boards</td>
</tr>
<tr>
<td>Cooperation in R&amp;D</td>
<td>Joint R&amp;D projects; presentation of research; supervision of trainees or Ph.D. students; financing of Ph.D. research; sponsoring of research</td>
</tr>
<tr>
<td>Sharing of facilities</td>
<td>Shared laboratories; common use of machines; common location of buildings; purchase of prototypes</td>
</tr>
<tr>
<td>Cooperation in education</td>
<td>Contract education or training; retraining of employees; working students; influencing university program curricula; providing scholarships; sponsoring education</td>
</tr>
<tr>
<td>Contract research and advisement</td>
<td>Contract-based research and consultancy</td>
</tr>
<tr>
<td>Intellectual property rights</td>
<td>Patent texts; co-patenting; licences of university-held patents; copyrights and other forms of intellectual property</td>
</tr>
<tr>
<td>Spin-offs and entrepreneurship</td>
<td>Spinoffs; start-ups; incubators at universities; stimulating entrepreneurship</td>
</tr>
</tbody>
</table>

Notes

1 An angel investor is a person who invests in a business venture, providing capital for start-up or expansion. These individuals are looking for a higher rate of return than would be given by more traditional investments (typically 25 percent or more). Angel investors are perceived as filling the gap between the financing provided by family and friends and venture capitalists.

2 Though comparable data for emerging Asian economies are not available, countries such as South Korea, China and Taiwan award a higher percentage of degrees in STEM than the mature industrial democracies.

3 These data are not drawn from random samples, and thus do not necessarily reflect national trends.

4 According to this law, a small number of authors are responsible for a high percentage of academic publications.

5 The cases of Michael Smith, winner of the Nobel Prize in chemistry 1993 at the University of British Columbia, as well as Jean-Pierre Adoul in telecommunications engineering at the University of Sherbrooke, are examples of the major role played by scholars in technology creation and transfer in two of the most entrepreneurial Canadian universities.

6 The ATP was formally abolished as part of the America COMPETES Act, signed in August 2007. It is to be succeeded by a new Technology Innovation Program, whose general mission will be similar to that of the ATP.

7 See the Advanced Technology Program Web site at http://www.atp.nist.gov/index.html

8 This was the core of the Fortier Commission’s (Expert Panel on the Commercialization of University Research) recommendations in 1999.

References


By almost every measure, Canada is one of the best countries in the world in which to live. Excellent health care, high-quality public education, well-functioning infrastructure systems, consistent economic growth and stable governance — no wonder so many other nations look with admiration at the quality of life we share in Canada. Nor is it a secret how we achieved our current status. Canada has advanced so far in a relatively short history because of careful, considered planning balanced against the pragmatic courage that characterizes societies like ours, built on the survival strategies of First Nations and the pioneering imagination and energy of immigrants.

As Jorge Niosi clearly outlines in “Connecting the Dots between University Research and Industrial Innovation,” Canada in 2008 has enormous knowledge resources, the capacity to produce innovative ideas and the desire to move forward. Yet, in spite of our current strengths, we are progressively falling behind our global economic competitors. In the most recent World Economic Forum Global Competitive Index, we slipped to thirteenth place in 2007-08, down one spot from the previous year (World Economic Forum 2007). In terms of our capacity for innovation, we now rank seventeenth in the world, behind the US and many East Asian and northern European nations.

Why are we slipping? We all aspire to a future in which Canada is a world leader in research, business, industry and the arts. We have spent a great deal of time pondering important questions: What is innovation? How can we promote it in Canada and increase our productivity? How can we position our innovations to compete in a changing global marketplace? In 2002, we created the Innovation Strategy; in 2006, the Expert Panel on Commercialization, of which I was a member, produced recommendations for improving commercialization (Expert Panel on Commercialization...
in October 2007, a new panel was struck to perform a competition policy review, now underway; and most recently, the Canadian government drafted its new Science Technology Strategy, laying out plans to stimulate technical innovations and train people to develop and use them.

It is clear that there is general acceptance that university-industry partnerships are quickly emerging. As Niosi suggests, complex, and they arise from a combination of factors, such as our strong reliance upon "resource-intensive industries whose firms have low or medium R&D intensity," and the existence of lower R&D intensity compared to our main G8 competitors “in selected large industries (particularly automobile manufacturing and the service sector)” (9). The fact that Canadians own very few large technology-intensive companies adds to the problem.

As Niosi suggests, given the scarcity of large Canadian firms, a focus on building university partnerships with major industrial firms, while important, can only take us so far. We must also pay particular attention to the potential for research partnerships with small and medium-sized enterprises (SMEs), which have fewer than 500 employees and are far more prevalent in Canada than large firms. This idea is not particularly new, but it has failed to gain widespread traction in the Canadian economic imagination and so still needs the analysis and explication that Niosi brings to bear in his study. Like many an innovative idea in this country, the idea that SMEs have a huge role to play in the commercialization of ideas and inventions seems to be in its own sort of “valley of death,” unable to bridge the gap between idea and action.

This failure to bridge the gap certainly is not indicative of an inability to recognize the problem. In fact, in the past two decades, a number of government initiatives designed to foster commercialization through partnerships between university research and SMEs have been put into place in Canada. We have the National Networks of Excellence, the National Research Council’s Industrial Research Assistance Program (IRAP), 4th pillar organizations, and the more recently established Centres of Excellence in Research and Commercialization. Small pockets of funding for early-stage commercialization have long been available through the tri-council funding agencies. In addition, provincial governments have acted; in Alberta, for example, Alberta Ingenuity has just launched the new Ingenuity Centres for Research and Commercialization program.
All of these programs have led, or promise to lead, to significant successes, but so far have failed to stimulate the widespread growth in innovation or the increases in productivity that Canada needs to effectively compete in the emerging global marketplace. When I served as a member of the six-person Expert Panel on Commercialization in 2005-06, we evaluated the programs that were then in existence, such as IRAP, 4th pillar organizations and programs in the tri-council agencies. Each has strengths and weaknesses; each provides valuable insight into how we might move forward. Yet none, in itself, is the solution.

Part of the problem is that almost all our existing commercialization programs focus on the supply side of the commercialization process, putting the onus on universities and researchers to create or search for demand. But, as Niosi argues, “Firms are better equipped to judge the commercial potential of technologies developed in universities, and they should play a central role in identifying those that are worthy of support” (16). If we agree with this assessment — and the Expert Panel on Commercialization certainly did — the question that must be answered is this: How do we induce Canada’s numerous SMEs to play this role — to partner with universities in identifying the commercial potential of technical discoveries? It won’t be easy, because, as Niosi also notes, for most “Canadian firms, other domestic and foreign companies are a much more important source of technology than universities” (10).

To ascertain how we might make it happen, Niosi points us to the model offered by the US Small Business Administration’s Small Business Innovation Research program (SBIR), a model that I too believe is worth a closer look. If we agree that a new commercialization model is needed — and all the evidence suggests that we do — then we should consider the successes that the SBIR has had in creating the access to top-quality university-level research that entrepreneurs need to advance their business goals.

The SBIR illustrates how a national program can create opportunities for SMEs to engage in and take advantage of high-level basic and applied research. This program, introduced in 1982, has now weathered more than a quarter century of scrutiny and assessment, including a comprehensive review requested by the US Congress and conducted by the US National Research Council. According their recently released findings, the SBIR plays a significant role in both stimulating innovation and promoting the growth of SMEs, as well as effectively linking both public and private markets to high-level research and enabling the dissemination of knowledge through a variety of means, ranging from patents and licences to spinoff companies and human capital (Wessner 2008).

The SBIR has the focus on the demand side of the commercialization process and the national mandate and breadth that Canadian programs have so far lacked. The US federal government’s Small Business Administration (SBA) administers the overall SBIR program by distributing funds through 11 US government funding agencies. Each agency solicits funding proposals from SMEs in response to very specific topics determined by agency needs. Thus, the proposals and research are directed to national priorities, and the economic feasibility of proposals and research is determined by the SMEs, which have the best knowledge of market needs.

Only SMEs located in the US are eligible to respond to solicitations. Proposing companies are strongly encouraged, though not required, to contract a university-based researcher to evaluate or conduct the basic research. Proposals are peer reviewed, to ensure relevance and quality, by program managers and their research teams working in the national laboratories of each agency.

As Niosi outlines, winners of an SBIR award follow a three-phase process: phase I is proof of concept (six months, up to $100,000, deliverable is a more extensive research plan); phase II is development of prototype (two years, up to $750,000, deliverable is prototype); and phase III is unfunded government assistance in capitalizing the advancement of the project. Many SBIR winners do not compete for phase II or phase III as their innovations, based on a strong research plan or proof-of-concept document, are picked up by investors, venture capitalists, or large corporate licensees who are interested in seeing the concept developed and taken to market faster than the SBIR process allows.

SBIR succeeds in achieving three major commercialization objectives that we, in Canada, want to attain. First, it effectively links SMEs to the research community, with the SMEs, rather than universities, identifying technical and scientific innovations that have the greatest potential to respond to market demands. In this, the SBIR model shares important characteristics with the “open innovation” model emerging in large corporations across the world. Second, SBIR provides entrepreneurs and SMEs with a way to bridge the “valley of death,” which often prevents a concept from progressing from the
model we devise, it must have leadership from industry and business, and demand from them active participation in setting commercialization priorities and in evaluating specific projects’ commercial viability.

Tom Brzustowski, in his book *The Way Ahead: Meeting Canada’s Productivity Challenge*, suggests that all existing and new provincial and federal research and commercialization programs be operated within one umbrella system. This would require harmonization of general administrative policies, criteria and processes across provincial and federal barriers and among various funding programs, but it would still allow for the regional or disciplinary differences between them. Brzustowski admits that implementation of his proposal would be difficult, but it would not be impossible if leadership in government, universities and industry were committed to making it happen (Brzustowski 2008).

There is no doubt that the development of a Canadian solution will require strong and decisive action from industry and business, government and universities working together. It will require us to identify the areas and markets in which Canada has the greatest potential to be a global leader, and put into place government policies and programs that strategically promote investment and innovation in these areas of national interest and stimulate the innovation capacity and growth of Canada’s numerous SMEs.

If we can succeed, we will inject new energy for seeking discoveries and breakthroughs throughout all sectors of the Canadian economy, and we will connect the SME community to a larger vision driving innovation. We can break out of the endless planning cycle we seem to be caught in and reawaken the pragmatic courage that built this nation. We can create both a system for success and a mindset of success — a mindset that prompts us to be highly connected and highly competitive. That strategy must be unique to Canada — putting the pressure on us, first and foremost, to be innovative in designing a strategy that connects and serves all the players in the innovation game: government, industry, universities, researchers and entrepreneurs.

prototype stage to product development. Third, when successful, the process leads to the development of new companies or the growth of established ones, the latter being of major concern in Canada.

To attain our objectives, there are important elements of the SBIR model that could be emulated. The recipients of an SBIR award can each play to their strengths. While the commercial aspects of the venture are handled by entrepreneurs with the right expertise, researchers are able to focus on their strengths and conduct research without distraction. The SBIR process provides the credibility of rigorous peer review — which validates the quality of the research plan while also controlling the entrepreneur’s risk in pursuing an innovative idea. Intellectual property rights are held by the SME with a royalty-free licence to the federal government in return for providing the initial funds. Last, but far from least, the SBIR puts the research and commercialization process on a clear and accountable timeline.

Is it possible for Canada to do the same? Can we put the commercialization process on a predictable, speedy timeline? Can we develop a standard national policy on intellectual property rights that will allow SMEs — or the larger organizations they may sell their innovations to — clear and defensible ownership of rights for ongoing development and international marketing purposes? Can we develop a commercialization model that will make the best use of peer reviewers from industry, university and government to evaluate proposals and select those that are most responsive to market demands and have the highest scientific merit and highest potential for success?

Although very successful in the US, the SBIR’s model cannot simply be cloned directly in Canada. We do not share the same kind of broad and diverse federal R&D structure through which funds can be distributed, and thus a model would need to be developed to suit Canada’s unique situation. The Expert Panel on Commercialization recommended that a business-led Commercialization Partnership Board be created to play both an advisory role to the Minister of Industry on identifying and setting national commercialization goals, and an oversight role on the development and implementation of commercialization policies, initiatives, investments and programs. Likewise, the Conference Board of Canada’s Leaders’ Roundtable on Commercialization proposed the creation of industry-led collaborative research networks.

The emphasis in both of these proposals on industry leadership indicates that whatever administrative elements of the SBIR model that could be emulated. The recipients of an SBIR award can each play to their strengths. While the commercial aspects of the venture are handled by entrepreneurs with the right expertise, researchers are able to focus on their strengths and conduct research without distraction. The SBIR process provides the credibility of rigorous peer review — which validates the quality of the research plan while also controlling the entrepreneur’s risk in pursuing an innovative idea. Intellectual property rights are held by the SME with a royalty-free licence to the federal government in return for providing the initial funds. Last, but far from least, the SBIR puts the research and commercialization process on a clear and accountable timeline.

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References


Notes

1 For a more complete discussion of the potential impact of these types of partnerships, please see Samarasekera (2008).

2 In a prepublication executive summary (available at http://www.nap.edu/catalog/11989.html), Charles W. Wessner, editor of An Assessment of the Small Business Innovation Research Program, writes that “just over 20 percent of companies responding to the NRC Phase II Survey indicated that they were founded entirely because of a prospective SBIR award” and the “companies responding to the same survey reported that over two-thirds of SBIR projects would not have taken place without SBIR funding” (Wessner 2008, 3).

3 Wessner also notes that one-third of SBIR respondents to the NRC survey involved universities in the following ways: “1. More than two-thirds of companies reported that at least one founder was previously an academic; 2. About one-third of founders were most recently employed as academics before founding the company; and 3. Some 27 percent of projects had university faculty as contractors on the project, 17 percent used universities themselves as subcontractors, and 15 percent employed graduate students” (Wessner 2008, 3).

4 Wessner’s complete list of “knowledge outputs” includes “data, scientific and engineering publications, patents and licenses of patents, presentations, analytical models, algorithms, new research equipment, reference samples, prototype products and processes, spin-off companies, and new ‘human capital’ (enhanced know-how, expertise, and sharing of knowledge)” (Wessner 2008, 2).

5 The 11 federal agencies include the following departments: Agriculture, Commerce, Defense, Education, Energy, Health and Human Services (including the National Institutes of Health), Homeland Security, Transportation, the Environmental Protection Agency, NASA and the National Science Foundation. Ninety-six percent of SBIR program expenditures are made by five departments: Defense, the National Institutes of Health, NASA, Energy and the National Science Foundation.

6 The National Institutes of Health, which assemble a national panel of external reviewers, are the exception to this.

7 For example, Procter & Gamble began developing its “connect and develop” innovation model in 2000 when it realized that its in-house R&D could not drive the kind of growth expected from a $70-billion company. Noting that the products that it had acquired from external sources performed well, CEO A.G. Lafley reformed P&G’s research strategy, acquiring 50 percent of its innovations from outside the company. Through “connect and develop,” P&G personnel “identify promising ideas throughout the world and apply [their] own R&D, manufacturing, marketing, and purchasing capabilities to them to create better and cheaper products, faster” (Huston and Sakkab 2006).
I am grateful for the opportunity to comment briefly on both the thoughtful study by Jorge Niosi and the response from Indira Samarasekera, President of the University of Alberta. As Samarasekera notes, the commercialization of university research has drawn increasing attention in Canada, but our performance is still lagging.

My own perspectives have been shaped by two decades of work in and around technology-based start-up companies. Although I see no quick fixes for our current malaise, I am optimistic about Canada’s ability to build and grow more successful innovation-based businesses.

Let us first ask, does Niosi have the diagnosis right? Is the problem primarily with research uptake rather than research output?

The answer, I believe, is a qualified “Yes.”

First, an important caveat: no one knows how many researchers and graduate students are required to create a thriving innovation economy. It is, of course, simplistic to say that more research output will solve the uptake problem, but it is also not clear that we have optimized the quality and quantity of outputs, as regards either the research undertaken or the graduate students being trained.

True, the higher education R&D (HERD) data reflect positively on Canada’s investment in research. But the reality is different than the figures on gross spending. Our universities are seriously underfunded compared to US peer institutions, even as research investment is growing rapidly in countries like China. In fact, the Canadian research pipeline is heavily underwritten by universities themselves, using their operating funds and philanthropic support — a factor overlooked in most intercountry comparisons.

In the context of global competition, the gap in per-student funding between Canada’s leading research universities and US universities is big and widening. A
simple example: the average per-student funding of private research-intensive universities in the US is 10 times the per-student funding of the University of Toronto; even for US public research-intensive universities, the average is more than twice as high.

In this context, there are no grounds for complacency about continued investments in funding excellent research and graduate training, as well as attracting outstanding talent to our universities and retaining it.

That caveat aside, as Niosi argues, our commercialization performance does lag behind our research publication rates. And I therefore support his argument that we rely unduly on a “supply-push” model of commercialization at our peril. This could be described as the “field of dreams” approach: “Patent it and they will come”!

Our neighbour to the south, in contrast, has enjoyed success with programs that create “demand pull,” such as the Small Business Innovation Research (SBIR) program and the Advanced Technology Program. Both programs provide support directly to industry with a view to drawing technology out of the university sector. I agree with Niosi and Samarasekera that programs of this nature are valuable. That said, neither program can be transplanted holus-bolus to Canada. Transplantation works only if there is a match between the donor and recipient — and our commercialization ecosystem is different from that of the US.

The US Pipelines Are Different

We shall now point out some of the similarities and differences between the US and Canadian innovation ecosystems.

Niosi suggests that, compared to the US, Canada is well positioned in the physical and related natural sciences because a higher overall proportion of university research in Canada is industry sponsored. I worry that the statistics may not be commensurate. Grants in the US from agencies such as the National Institutes of Health and the National Science Foundation partly cover personnel costs and fully cover the institutional costs of research. The denominator of total research funding is therefore higher in the US. The valid comparison is per capita rates of industry-sponsored research funding, with adjustment for differences in overheads, broken out by disciplines. I have never seen that comparison published.

The comparison is further confounded by significant agency and military-sponsored strategic research in the US. Agencies such as the Defense Advanced Research Projects Agency (DARPA) and other branches of the US military establishment fund applied and, in some cases, basic research that advances technologies in a focused manner through the proof-of-concept stage and both directly and indirectly feeds into larger and smaller enterprises, including those supported by programs such as the SBIR.

The US government (through a diverse array of agencies) also supports a strong network of national laboratories. Entities such as Pacific Northwest National Laboratories, Oak Ridge, Ames and Sandia carry out targeted research, a significant proportion of which is positioned for conversion into industrial applications in fields such as energy, environment and advanced manufacturing. In Canada, the federal government and some provincial governments have tried, through a variety of programs, to grow similar strategic capacity. However, there is a recurrent tendency to confuse regional development with research commercialization. The location of US national laboratories has also been subject to political and regional forces, but, as a result of funding models that require them to compete for research grants and industrial contracts, their operational framework is more disciplined than most analogous enterprises in Canada today. As a result, a US laboratory such as Oak Ridge competes with the best universities in the world in material science, as measured by research output in leading scientific journals.

The US Receptors Are Different

There are also marked differences between Canada and the US in the commercial environments that draw discoveries and technologies out of universities. Many university-based discoveries are well upstream from the market. They can only be developed by sophisticated research-intensive industrial partners or through the creation of new companies supported by substantial risk capital.

R&D spending in Canadian industry remains well below US numbers. And Canadian industry is still dominated by small and medium-sized enterprises with limited research capacity; larger firms are often either resource companies (and thus cushioned from innovation pressures by global market demand) or
branch plants of international firms with R&D centres elsewhere. The result is a lack of head office decision-making in Canada on research investment, and particularly on development of research innovation.

Creating and growing new Canadian companies that can convert our important discoveries into global products is much more challenging than in the US for other reasons as well. Entrepreneurial researchers in Canada face a paucity of proof-of-concept funding as well as early-stage equity capital from either angels or institutional sources compared to the US. The early-stage investment climate in Canada is less mature than in the US — institutional seed funds only emerged in the late 1990s and were all but wiped out by the collapse of the technology bubble after 2001. The Canadian angel investment community is less active in the technology sector than US investors. Canadian venture funds are typically smaller than their US counterparts; as a result, they tend to invest less per company and often struggle to support their investee companies through the entire growth cycle. There is also a marked difference between the investment approach and risk appetite of early-stage fund managers in Canada versus the US: successful US funds tend to be populated by industry experts and former entrepreneurs, while many Canadian fund managers migrated into venture capital from the financial sector. By nature, they prefer to invest in later-stage, revenue-generating prospects. It is true that, even in the US, venture capital is concentrated in hot spots like Silicon Valley or Boston. Nonetheless, there are many sources of seed-stage and follow-on funding for US start-up executives to access, and they know where to find them.

A related constraint is that the Canadian market is small compared to that of the US. Not only are our technology entrepreneurs fewer in number, but they must also be globally oriented more or less from the outset. In some important knowledge sectors, like health, the already small Canadian market for adopting Canadian innovation is further balkanized into provinces, and spending on research/innovation is often viewed as a cost in our system, not an investment.

This leads to a virtuous cycle in the US and a vicious cycle in Canada. Fewer of our companies mature to the scale where both investors and entrepreneurs reap major financial rewards. In the US, a virtuous cycle fuels the reinvestment of capital and the development of a pool of seasoned executives — serial technology entrepreneurs who know how to grow companies big.

Furthermore, our hub cities, the most likely regions where university technologies might find early adopters, are very geographically dispersed. This makes it more challenging to transfer technologies to companies in close proximity to the university. It also means that new companies based on those technologies need to find their early adopter customers farther afield. Without sufficient capital, patient investors and strong management with international experience, these companies face significant hurdles.

Made-in-Canada Solutions

In the absence of a strong funding infrastructure for strategic and applied research or a mature ecosystem for company creation, Canada’s innovation economy lets some competitor jurisdictions get a head start. Moreover, at risk of belabouring the obvious, we cannot just cruise along on our natural resources. Canada has to build a competitive innovation-based economy and, as Samarasekera urges, the time to do so is now. What, then, can we do?

First, we cannot be the US in miniature — even if we wanted to be. Our population is small, and our industrial base and political culture are both different. That means Canada should study a wide range of jurisdictions for practices and policies we can borrow.

Second, we need to take a hard look at some of our current investments in the applied research and commercialization sphere. This includes programs that fund industry collaboration through Canadian granting councils, federal applied research laboratories and centres of excellence, as well as the programs supported by the Business Development Bank of Canada (BDC). We should measure them against best practices and policies in other jurisdictions and be willing to redirect those funds or add to them dramatically, depending on the results. A small population, with a vast geography and a strong culture of regionalism, cries out for new models of collaboration to create focal points with a critical mass of ideas, talent and capital that can compete on a global scale.

Third, when in doubt, as Niosi and Samarasekera argue, we should invest on the demand-pull side. NRC’s Industrial Research Assistance Program (IRAP) is situated in this space. The same might be said of 4th pillar initiatives, such as Precarn, which straddle academe, government and industry. These models are appealing because they hinge on collaboration between industry
and academe, with identified customers or market applications. When all is said and done, academic institutions and granting councils have commercialization only as a secondary objective and they are short on the business skills and market contacts critical to a demand-pull strategy.

Fourth, governments should take further creative steps to transform technology transfer in our universities and research hospitals. The federal government has done so recently, with its backing of a program to establish Centres of Excellence for Commercialization and Research (CECR). Although the first wave of investments was research-oriented, a number of centres funded subsequently will focus more on commercialization than on research itself. This is a welcome development. It is imperative that these centres explore new approaches and be evaluated rigorously to disseminate new learning. Similarly, I hope that the new business-led centres of excellence programs will catalyze further engagement by industry in setting priorities and direction for collaborative research in areas of strategic importance to the Canadian economy.

At risk of local boosterism, I note that one such centre is MaRS Innovation — a member-based consortium of 14 university and hospital research institutions in downtown Toronto. Together, these institutions represent over $1 billion of externally funded research. MaRS Innovation will act as a common, integrated commercialization vehicle for all 14 institutions — with the ability to bundle inventions into more marketable packages, to launch companies based on robust IP platforms and to develop market expertise in areas of shared research strength. Perhaps most importantly, MaRS Innovation will create a single business-friendly point for interfacing with industry, investors and entrepreneurs — bringing together the best of Toronto's discoveries from multiple institutions, but based outside of academe. This is an important model to explore and develop further.

Fifth, beyond technology transfer, space and place matter. Canada has a growing number of science parks and incubation spaces, as well as multi-tenant facilities that draw together academic researchers, start-up companies and private-sector entities active in commercialization (for example, service provider firms, angels and venture funds). MaRS itself is an example of this latter model. MaRS focuses on the demand-pull side of the equation, doing market research for young companies, providing incubation and business advisory services, linking to the relevant industry leaders, and connecting emerging companies to the local and international angel and venture capital communities.

Sixth, and this is a critical item, we need bigger pools of smart venture capital, focused on innovation-based companies. As has occurred in other small jurisdictions, such as Israel, governments will need to contribute to start the cycle of investment. The recently announced Ontario Venture Capital Fund — for which $90 million of the approximately $200 million comes from the government itself — exemplifies this trend, and will hopefully catalyze the formation of new funds in the market. Venture philanthropy models, which bring a disciplined investment approach to the deployment of donations in translational research or market validation projects, are also worth exploring.

The final step is the most difficult and perhaps the most crucial. We need a shift in national Zeitgeist. In recent years, I have been struck by the fact that more and more Canadians are expressing unease about our prospects for long-term prosperity as a nation. I hear concerns about our lack of an entrepreneurial culture and the difficulty of creating a coherent national strategy for commercialization when economic oversight is fractionated among three levels of government. I also hear and endorse more optimistic views based on our extraordinary history of adaptability as one of the world’s most successful experiments in democratic pluralism. But, adaptable or not, Canadians are losing ground. We urgently need bold vision and bolder decisions if Canada is to compete and win in the rapidly changing global economy.
Le Canada investissant beaucoup dans la recherche universitaire sans en recoller les fruits en matière d’innovation industrielle et de productivité, Jorge Niosi examine dans cette étude les modes de transfert vers le secteur industriel des technologies issues des universités.

Pour structurer son analyse, il établit un modèle d’offre et de demande d’innovations qui prévoit que les avancées scientifiques produisent à terme des technologies commercialement rentables. C’est du côté de l’offre, dominée par la recherche universitaire, que les idées se transforment en concepts, en études et en découvertes utiles. Et comme les avantages économiques de cette recherche sont à la fois dispersés et difficiles à prévoir, les gouvernements tendent à y investir de fortes sommes. De fait, estime l’auteur, l’offre universitaire en technologies innovantes se porte plutôt bien au Canada selon des indicateurs comme l’investissement dans la R-D universitaire, le nombre de diplômés en sciences et en génie, et les taux de publications savantes.

Du côté de la demande, soit à l’autre extrémité du pipeline de la recherche universitaire, les entreprises miscent sur des technologies clés pour concevoir des produits et des processus rentables, qui exigent souvent un surcroît d’investissement en R-D. Mais plusieurs facteurs, dont l’étroitesse relative et l’étendue géographique du marché canadien, jouent en défaveur d’une forte demande comparative aux États-Unis. L’auteur constate que la demande en recherche universitaire est étonnamment faible ici — excepté dans certains secteurs comme ceux des produits pharmaceutiques et de l’équipement électronique —, la plupart des entreprises canadiennes se tournant vers d’autres firmes pour se procurer des technologies brevetées. Ce qui confirme indirectement qu’elles ne trouvent pas ce qu’elles cherchent dans les universités.

Pour qualifier cette zone grise entre l’offre et la demande de technologies issues des universités, l’auteur parle de « vallée de la mort », en raison d’un financement insuffisant mais aussi d’attentes incompatibles. Pour les entreprises, les universités représentent une source potentielle de technologies qu’il leur serait trop coûteux et risqué de développer au stade initial. Mais dans le monde universitaire, les professeurs sont d’abord motivés par la publication de leurs recherches dans des revues spécialisées qui privilégient l’originalité au détriment du potentiel commercial.

Au Canada, la majorité des efforts visant à trouver des débouchés commerciaux aux technologies issues des universités passent par des bureaux universitaires de transfert de technologie. Ceux-ci ont pour tâche d’évaluer le potentiel commercial des technologies, de protéger leur propriété intellectuelle, de répartir les redevances et de chercher des exploitants de brevet, essentiellement selon une approche d’offre-incitation. Mais ces bureaux ne possèdent ni la connaissance du marché ni les effectifs nécessaires à un transfert efficace.

Jorge Niosi estimerait beaucoup plus fructueuse une approche fondée sur la pression de la demande, selon laquelle les entreprises sollicitent et stimulent la création des technologies issues des universités. Il fait valoir en ce sens plusieurs initiatives américaines. Les programmes Small Business Innovation Research (SBIR) et Small Business Technology Transfer Research (STTR) assurent ainsi aux PME un financement de démarrage pour le développement initial de technologies mené en collaboration avec des chercheurs universitaires. Et le Advanced Technology Program (ATP) aide les entreprises, notamment en les associant directement aux priorités de la recherche universitaire, à commercialiser des technologies génériques. L’auteur précise toutefois qu’une loi inspirée du Bayh-Dole Act de 1980, qui accorde des droits de propriété intellectuelle aux inventeurs plutôt qu’aux bailleurs de fonds, serait inefficace au Canada.

Dans le contexte canadien, toute approche du transfert de technologie universités-entreprises fondée sur la pression de la demande devrait avoir pour premier objectif d’associer les entreprises à l’élaboration des programmes de recherche universitaire sans leur permettre d’en dicter tout le contenu. Bon nombre des recommandations du Groupe d’experts sur la commercialisation seraient donc inadaptées à cet égard, puisque les décisions relatives aux technologies à financer resteraient réservées aux universités et aux gouvernements. Aussi l’auteur propose-t-il de créer des programmes inspirés du STTR et de l’ATP américains dans le cadre de l’actuel Programme d’aide à la recherche industrielle, à la fois efficace et apprécié des intéressés.

Les deux commentatrices offrent le point de vue respectif du monde universitaire et des milieux d’affaires. Indira Samarasekera, présidente de l’Université de l’Alberta, souscrit à l’essentiel du diagnostic de l’auteur et propose de rapprocher les PME des universités, puisque les partenariats universités-entreprises se limitent actuellement à un petit nombre de grandes entreprises. Ilse Treurnicht, chef de la direction du Centre d’innovation MaRS, observe que le système d’innovation des États-Unis diffère sensiblement du nôtre et que l’approche en série des programmes américains pourrait se révéler moins efficace au Canada. Mais elle convient de l’importance cruciale d’associer les entreprises aux programmes de recherche universitaire, celles-ci possédant une connaissance du marché qui fait défaut aux universités et organismes subventionnaires.
Summary

In this study, Jorge Niosi examines the channels by which university-developed technologies are transferred to industry. Canada invests large sums in academic research, but the fruits of these investments are not reflected in more industrial innovation and improved productivity.

To frame the analysis, Niosi lays out a supply-demand model of innovation according to which basic discoveries and advances in frontier science ultimately bear fruit in the form of commercially viable technologies. The supply side is where ideas are organized into useful concepts, research and discovery, and it is dominated by university research. Because the economic benefits of such research are broad in scope and difficult to predict, governments tend to be heavily involved in financing it. Using indicators such as investment in university research and development (R&D), numbers of science and engineering graduates and scholarly publication rates, Niosi concludes that the supply side of university technologies is reasonably healthy in Canada.

At the demand end of the university research pipeline, businesses build on basic technologies to develop commercially profitable products or processes, which often require complementary investments in R&D. Niosi points out that several factors—notably Canada’s relatively small and geographically dispersed domestic market—work against strong demand for technology here compared with in the United States. Despite pockets of strength in the pharmaceutical and electronic equipment industries, demand for university research is surprisingly low. The author notes that most Canadian companies turn to other firms for licensed technology, which is circumstantial evidence that they are not finding the technologies they need in universities.

Niosi terms the grey area between the supply and demand of university-developed technologies the “valley of death,” not only because of the paucity of funding, but also because of mismatched expectations. From the perspective of business, universities provide a potential vehicle for developing early-stage technologies that would otherwise be too risky and costly. However, from the perspective of academia, professors are primarily motivated by scholarly publication of their work, for which commercial potential is typically much less important than originality.

Currently in Canada, most efforts to connect university-developed technologies to potential commercialization opportunities pass through academic offices of technology transfer (OTTs). OTTs are charged with evaluating the commercial potential of these technologies, securing appropriate intellectual property protection and division of royalties, and seeking out potential licensees—essentially a supply-push approach. But they have neither the human resources nor the market knowledge to provide effective technology transfer.

Niosi suggests that a demand-pull approach, by which businesses seek out and cultivate university technologies, would be much more useful, and points to several US initiatives that have proven effective. These include the Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) programs, which provide seed funding to small- and medium-sized enterprises for early-stage technology development in cooperation with academic researchers. In addition, the Advanced Technology Program (ATP) helps companies commercialize generic technologies, in part by involving them directly in university research priorities. By contrast, says Niosi, legislation along the lines of the landmark 1980 Bayh-Dole Act, which grants intellectual property rights to the inventors rather than the funders of technologies, would be ineffective in Canada.

In the Canadian context, the key objective in developing a demand-pull approach to university-industry technology transfer would be to involve businesses in the development of academic research agendas without allowing them to dictate those agendas entirely. Many of the Expert Panel on Commercialization’s proposals are lacking in this regard, because they would keep decisions about what technologies to fund in the hands of universities and governments. The author proposes that Canada create pilot programs along the lines of the STTR and ATP under the rubric of the successful and well-regarded Industrial Research Assistance Program.

Two commentators provide university and industry practitioner perspectives. University of Alberta President Indira Samarasekera broadly agrees with Niosi’s diagnosis of the problem, and emphasizes that, given that university-industry partnerships are currently limited to a small number of large firms, policies must better connect small and medium-sized enterprises to universities. Ilse Treurnicht, head of the MaRS innovation consortium, cautions that the US innovation ecosystem is quite different from that of Canada, which means that a cookie-cutter approach may not be very effective. She agrees, however, that businesses should be involved in developing academic research agendas, because they have the market knowledge that universities and granting councils lack.
Meeting Canada’s Full Potential: Building World Class Partnerships

A Submission to the House of Commons Standing Committee on Finance - August 13, 2010
Executive Summary

This is Canada’s year. We have the foundation, the vision, the resources and the will to be a global leader. However we are not effectively leveraging our strengths to address the challenges facing our nation and our world. It is imperative that we address these challenges in order to fulfill our potential and secure Canada’s position on the international stage.

Countries such as India and China are effecting a global shift. They are demonstrating leadership by aggressively pursuing strategic world-class collaborations and partnerships, thereby securing their prominence in the world order.

Not only should Canada be following the example of China and India but we should be leading the development of innovative partnership networks. However, a critical gap exists in the current federal funding structure: while Canada’s pre-eminent universities are diligently seeking world-class partnerships with global organizations and individuals, these same institutions are losing out when they are unable to leverage appropriate funds in a timely manner to take advantage of these critical opportunities. This loss is three-fold: our universities lose out on invaluable partnerships; our competitors exploit those same partnerships to their advantage and to our nation’s detriment; and significant foreign investment that can only be brought to Canada by universities is lost.

The Recommendations

1. Canada should create a Creative Global Partnerships Fund that has at its core an emphasis on speed and agility that will allow for development of all forms of pre-eminent partnerships.

2. Canada must target, pursue and engage world-class partners and collaborations domestically and abroad.

3. The government should review, with disciplined focus, its funding and policy objectives and commitments through a strong partnership and collaborative lens.

The power of partnership will play a commanding role in the coming years; Canada’s prosperity depends on the Government of Canada’s continued commitment to advancing our nation’s competitiveness. This has been Canada’s year; we have the power and vision to make it Canada’s century.

Monetary Fund (IMF) and other international players have cited Canada’s general financial framework as a model, our productivity is lagging. This lag is predicted to become a serious hindrance to Canada’s global competitiveness and a detriment to Canadians’ quality of life.

In its 2008 report, Compete to Win, the Competition Policy Review Panel states:

We as a country need to regain our ambition to be the best. We cannot be content with simply being in the top ten or top twenty among international competitors. Globalization and the accelerating pace of change will continue whether or not we step forward to address these fundamental transformations. If we want to control our destiny, we must acknowledge these issues and deal with them.

Currently, Canada is ranked among the top ten most competitive nations by respected organizations; the World Economic Forum rated us ninth in its 2009-2010 Global Competitiveness Report. Canada’s competitiveness has been steadily improving, indicating that our nation’s forward momentum is growing. However, as TD Economics and other sources have noted, our comparatively low productivity and lack of business innovation are an important factors slowing further progress. As Kevin Lynch, Vice-Chair of BMO Financial Group, has stated:

In this changing world order, growth and progress are not preordained. Neither are they circumscribed. The challenge is how well we respond to these trends, and tackle them with a sense of urgency, not complacency; an emphasis on speed and agility, rather than process and entitlement. […]Canada needs a more global orientation, in our mindsets, in our networks, in our public policies, in our universities and in our business planning. We must react strategically to the rise of Asia […] and the shifting of global economic power.

Moving Canadian businesses to the forefront in the global marketplace will require a collective effort by key players in the public and private spheres. The pursuit of partnerships with the best and brightest on the international and local levels will be critical to Canada’s success in reaching for global excellence and controlling our international destiny. As stated in Mobilizing Science and Technology to Canada’s Advantage,

“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.”

While formal ties between institutions, businesses and governments are necessary for the continued success of col-
Building the Foundation

For nearly two decades, the Government of Canada has been making strategic decisions in the development of policies and programs that have built a strong foundation for innovation and competitiveness. Further, the Government of Canada recognizes the value of building on that foundation. In fact, searching for international examples of ways to better capitalize on national investments in research, a 2007 publication by the National Academies in the United States entitled *Innovation Policies for the 21st Century* featured the Canada Research Chairs (CRC) and the Canada Foundation for Innovation (CFI) as examples of programs that could be emulated in the United States. Among the stellar programs funded by the Government of Canada, the Tri-Councils, the Canada Foundation for Innovation, the Canada Research Chairs (CRC) and, most recently, the Canada Excellence Research Chairs (CERC), the Knowledge Infrastructure Program (KIP), the Vanier Scholarships and the Banting Postdoctoral Fellowships Program have provided and will continue to provide Canada with the solid base required to achieve our world-class goals.

*Advantage Canada and Mobilizing Canada’s Science and Technology to Canada’s Advantage* strategically identify the essentials to ensuring global competitiveness and success: People, Knowledge and Entrepreneurial Advantages. The creation of such flagship programs as the Canada Excellence Research Chairs and the Vanier Scholarships has already impacted Canada’s research landscape by attracting some of the top minds in science from around the world. Indeed, the individuals who have been recruited through the CERC’s and the Vaniers have been hailed as significant “brain gain” for Canada. The researchers and their teams who have relocated to our country under the CERC program will act as powerful connectors and enablers for international collaborations and partnerships. They link Canada into their existing global networks. These luminaries act as ambassadors to the globe, and will contribute to the “talent super-magnet” phenomenon, attracting world leading researchers and students from around the globe to work and study in Canada. The Banting Postdoctoral Fellowships Program, announced in Budget 2010, will strategically enhance Canada’s ability to attract top international talent by supporting researchers who are on the path to greatness.

The pursuit of strategic partnerships with the best and brightest on the international and domestic levels will be critical to Canada’s success in reaching for global excellence and controlling our international destiny.

Leveraging Partnerships into Enhanced Canadian Competitiveness

The importance of partnerships is stressed throughout the federal government’s strategic documents, has been championed by numerous Parliamentarians and was a core component highlighted by the Competition Policy Review Panel. In *Mobilizing Science and Technology*, the Government of Canada acknowledges the importance of looking at science and technology collaborations from an international rather than strictly national perspective:

“Canada must be connected to the global supply of ideas, talent and technologies – as a contributor and in order to adopt and adapt important innovation for the benefit of Canada [...] Canada needs to do more to encourage international collaboration in order to access the tremendous knowledge being generated elsewhere and lever the enormous potential.”

The Canada Excellence Research Chairs, the Banting Postdoctoral Fellowships Program and the Vanier Scholarships are key tools needed to advance Canadian competitiveness and secure Canadian prosperity. As global research ‘stars’ are drawn to Canada, they shape the market in their area of expertise, drawing like-minded people to their location and, when a critical mass of such people is achieved, form a knowledge cluster. Such a cluster positively influences the competitiveness of the region and nation. Canada’s ability to capitalize on the strategic opportunities presented by knowledge clusters and find effective and innovative solutions to domestic and international challenges will be directly linked to our ability to advantageously partner with global innovators and compete at the very highest levels on the international stage.

International connections to ideas, talent, technology, facilities, capital and collaborations can be made through partnerships. The value of these partnerships cannot be underestimated nor can the importance of public support of those partnerships:

“Partnerships of researchers and entrepreneurs are important because they bring research strengths to bear on market-driven challenges and opportunities. There is a role for public support for such partnerships because the
benefits they provide spread across the economy. The cost, complexity, and pace of scientific achievement today—along with the complementary skill sets that exist in the industrial, university, and public sectors—demand the creation of smart partnerships.

An exemplary Canadian organization that facilitates the creation of international research collaborations in Canadian universities by constructing partnerships with businesses, government and not-for-profits is the Mathematics of Information Technology and Complex Systems (MITACS). Of its programs, MITACS has two that are designed to attract international talent to Canadian universities: the Globalink Program and the Accelerate Program. Since its inception in 2008, the Globalink Program has attracted 122 Indian undergraduate students to conduct research projects in Canadian universities for a three to four month period. This program fosters the transfer of knowledge, facilitates the development of informal and formal networks and promotes Canadian universities in India. Further, the Accelerate Program, a national four-month internship program, connects companies and organizations with Canadian universities. This program offers graduate students and post-doctoral fellows the opportunity to intern with partner companies or organizations at home and abroad. Students gain knowledge from their work and research experience, bringing new ideas home to Canada.

Canada’s current and future competitors are the nations that broker partnerships to enhance their interests on the global stage. Countries such as India and China are prime examples of a global shift; they are demonstrating global leadership by aggressively pursuing strategic world-class collaborations and partnerships. Also, the European Union, itself an important partnership entity, continues to advance research and development through enhanced funding.

The Government of Canada has recognized the importance of India in the current and future world order and has actively pursued partnerships with that nation. Moving forward, the Canadian government should look to innovative partnerships in India as a model for the development of future programs. For example, the Government of India initiated the New Millennium Indian Technology Leadership Initiatives (NMITLI) in 2001. According to the 2009 annual report for the program, NMITLI is the largest public-private-partnership R&D Programme in the country and synergizes the best competencies of publicly funded R&D institutions, academia and private industry. The program has developed 57 projects in diverse areas. These projects involve 80 industry partners and 270 R&D groups comprising approximately 1700 researchers from different institutions. These highly flexible, collaborative partnerships have changed how post-secondary institutions and multinational conglomerates, such as Tata Corporation, work together.

The University of Alberta has been diligently forging connections with the Indian government, institutions of higher learning, businesses and innovators. There are over 400 students from India studying at the University of Alberta and over 75 Indian academics currently on staff. Dr. Sushanta Mitra was recruited from India and is the director of the Micro and Nanoscale Transport Laboratory at the National Institute for Nanotechnology (NINT) housed at the University of Alberta. Since his arrival in 2008, Dr. Mitra has recruited nine students from across India to the University of Alberta for graduate studies and has sent Canadian graduate students to work in labs in India as part of their program in Canada. Dr. Mitra engenders two-way visiting by regularly returning to India and hosting Indian colleagues as visiting scholars in his lab.

Further, the University of Alberta has collaborations and exchange agreements with several important Indian institutions and organizations including the prestigious Indian Institute of Technology Bombay (IIT-Bombay), the Petrotech Society of India, the Public Health Foundation of India, and Tata Consultancy Services Limited. The University of Alberta’s five-year partnership agreement with Tata Consultancy Services, a global corporation with over 110,000 employees and operations in more than 50 countries, features student internship opportunities and researcher exchanges in the areas of science, information communication technology and engineering, among others.

Like India, China’s place of prominence in world affairs and the global economy has been growing steadily for the past two decades. A key component of China’s aggressive program of development and reform has been the pursuit of world-class partnerships with other nations, international institutions and industries. Canada has become one of China’s key partners.

The University of Alberta has deep and long-standing relationships with China. Currently, there are almost 2000 students from China studying full-time at the University of Alberta and 70 active members of the University of Alberta Association of Chinese Canadian Professors. The University of Alberta has 60 memoranda of understanding with a broad variety of universities, research institutes, government agencies and administrative institutes in China. These MOUs have allowed for a flow of people and knowledge between the two nations. For example, joint research labs have been established for nearly a decade between Key State Laboratories of the Ministry of Science and Technology (MOST) and select University of Alberta labs—no other foreign university

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Canada’s ability to capitalize on strategic opportunities and find effective and innovative solutions to challenges will be directly linked to our ability to advantageously partner with global innovators at the very highest levels.
has such an agreement with MOST. Funded by a multitude of industry players and the Natural Sciences and Engineering Research Council of Canada (NSERC), Dr. Zhenghe Xu holds a research chair in advanced coal cleaning and combustion technology. Dr. Xu’s partnership with MOST gives him and his graduate students access to two of China’s Key State Laboratories while also providing Chinese graduate students the opportunity to conduct research at the University of Alberta.

Further, the Li Ka Shing Foundation recently gave the University of Alberta the largest cash donation in the university’s history. Along with a donation from the Government of Alberta, the funds established the Li Ka Shing Institute for Virology. Part of the Foundation’s donation will help extend the university’s connections to Shantou University Medical College, with the launch of the Sino-Canadian Exchange Program—a joint Ph.D program between the two medical schools. With the establishment of the Institute, the University of Alberta joins the East West Alliance, a global network of medical education and research funded by the foundation which includes many prominent universities such as the University of California at Berkeley, Oxford University and Cambridge University in the United Kingdom and the Institut Pasteur in France.

Another exemplary partnership with a private Asian corporation at the University of Alberta is the $14 million Hitachi Electron Microscopy Products Development Centre. This venture is a collaboration of the University of Alberta, Hitachi High-Technologies Canada, Inc., the National Research Council (NRC) and Alberta Ingenuity Fund’s nanoWorks program. The centre houses three electron microscopes, one of which is the only one of its kind located outside of Japan, worth $7 million that give researchers the tools needed to make important discoveries in nanotechnology from oil sands processing and industrial coating to solar energy and diagnostic devices. University of Alberta researchers and Hitachi are collaborating to bring leading-edge research to the marketplace. This centre, located at the National Institute for Nanotechnology (NINT) at the University of Alberta, is the first project announced under the new Western Economic Partnership Agreements between the Governments of Canada and Alberta. NINT, a partnership itself between the National Research Council of Canada, University of Alberta, and Government of Alberta “[…] combines the strengths of a federal laboratory and a university to position Canada at the forefront of nano-scale discoveries […]” and was the magnet that attracted Hitachi to Canada. The institute continues to attract international talent, technology and partners and to act as a catalyst for international networks and partnerships.

On the European front, the European Union has created an outstanding example of publicly-supported partnerships: the cooperation in Science and Technology (COST) program. COST, one of Europe’s major research granting programs, is a collaboration of 36 European countries and currently provides funding for close to 300 research projects that bring together scientists from at least five countries. Despite the economic uncertainties facing the European Union, it has announced a €40 million increase for this program, making its total budget €250 million over the next three years. The director of the program has expressed interest in enabling closer collaborations between European and Canadian scientists. In addition to bolstering the funding for COST, the European Union recently announced an investment of €6.4 billion in research and development, with the goal of increasing Europe’s competitiveness while providing the creation of jobs and other economic stimuli.

The University of Alberta’s relationship with European institutions has come to the fore in the form of the Helmholtz Alberta Initiative, which is a partnership formed in 2009 between the University of Alberta and Germany’s largest scientific organization, the Helmholtz Association of German Research Centres. The Association encompasses 16 research centres, 30,000 employees and has an annual budget of approximately €3 billion. The partnership covers research topics such as the environmentally-responsible development of oil sands, carbon capture and storage, geothermal energy and land and water reclamation, opening up new opportunities for technology transfer and collaboration with business and industry. Although the partnership is in the early stages, the plan is for extensive graduate student and researcher exchanges, with two-way visiting between Germany and Canada. The Helmholtz Alberta Initiative has already led to a number of discussions to expand the partnership into other areas of strategic interest.

Clearly, the examples cited above provide a strong indication of the trends driving the global research and innovation marketplace. The promotion of key partnerships such as these either in Canada or with Canadian partners will stimulate the exchange of talent, ideas and innovation related to science and technology, encouraging greater innovation in the private sector. These outstanding partnerships will also enable Canada’s leaders in research, innovation, universities, the not-for profit sector and industry to influence global commerce and economic, public and social policy. This influence, combined with the resulting scientific and technological advances, will help to position Canada, Canadian firms and Canadian researchers, innovators and opinion makers as global leaders and agenda setters.

There is, however, a critical gap in the current funding structure: while Canada’s pre-eminent universities are diligently seeking world-class partnerships with global organizations and individuals, these same institutions are
Our universities lose out on invaluable partnerships; our competitors exploit those same partnerships to their advantage; and significant foreign investment that can only be brought to Canada by universities is lost.

losing out when they are unable to leverage appropriate funds in a timely manner to take advantage of these critical opportunities. This loss is three-fold: our universities lose out on invaluable partnerships; our competitors exploit those same partnerships to their advantage and to our nation’s detriment; and significant foreign investment that can only be brought to Canada by universities is lost.

The Recommendations

In order to take Canada to the next level of global competitiveness, advance the recommendations found in Compete to Win and leverage Mobilizing Science and Technology, the Government of Canada must persevere on the path mapped out in these foundational documents.

In order to do this:

1. **Canada should create a new Creative Global Partnerships Fund that has at its core an emphasis on speed, agility, innovation and creativity that will allow for development of all forms of pre-eminent partnerships.**

This new fund would equip Canadians with the tools they need to compete with the best worldwide and would:

- Be flexible, open, agile and strongly merit-based.
- Be internationally peer reviewed.
- Fill the gap that currently exists for a flexible mechanism for rapid deployment of federal funds that facilitates global multi-partner initiatives.

- Be in addition to, and separate from, existing budgets of the Granting Councils.
- Be administered by the Granting Councils.
- Leverage public funds for greater returns on investment by enabling partnerships with world-class organizations such as the Wellcome Trust, the Li Ka Shing Foundation and the Gates Foundation.
- Keep pace with global scientific discovery and business innovation.
- Build momentum and widespread excitement as Canadian businesses and higher education engage the world with revolutionary partnerships.

2. **Canada must target, pursue and engage world-class partners and collaborations domestically and abroad.**

Canada must be single-minded in this approach and focus on areas that are in, or ought to be in, Canada’s strategic national interest. The result of this kind of disciplined approach will be the attraction of world-class talent, ideas, technology and capital.

3. **The government should review, with disciplined focus, its funding and policy objectives and commitments through a strong partnership and collaborative lens.**

This partnership lens must ensure that both domestic and international partnerships and collaborations are world-class. Canada must not settle for just any partner or collaboration.

The power of partnership will play a commanding role in the coming years; Canada’s prosperity depends on the Government of Canada’s continued commitment to advancing our nation’s competitiveness. This has been Canada’s year; we have the power and vision to make it Canada’s century.
Entrepreneurial Impact: The Role of MIT

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February 2009
Entrepreneurial Impact: The Role of MIT

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The views expressed herein are those of the authors and do not necessarily reflect the views of the Ewing Marion Kauffman Foundation or MIT. Any mistakes are the authors’.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive Summary</td>
<td>4</td>
</tr>
<tr>
<td>Economic Impact of MIT Alumni Entrepreneurs</td>
<td>4</td>
</tr>
<tr>
<td>The Types of Companies MIT Graduates Create</td>
<td>5</td>
</tr>
<tr>
<td>The MIT Entrepreneurial Ecosystem</td>
<td>6</td>
</tr>
<tr>
<td>The Role of MIT Alumni Companies in the U.S. Economy</td>
<td>8</td>
</tr>
<tr>
<td>Additional Trends over the Decades</td>
<td>9</td>
</tr>
<tr>
<td>Growth in Numbers</td>
<td>9</td>
</tr>
<tr>
<td>More Diverse Entrepreneurs</td>
<td>10</td>
</tr>
<tr>
<td>Younger Entrepreneurs</td>
<td>12</td>
</tr>
<tr>
<td>Serial Entrepreneurs</td>
<td>14</td>
</tr>
<tr>
<td>MIT Founders and MIT Course Majors</td>
<td>16</td>
</tr>
<tr>
<td>Industry Composition and Effects</td>
<td>17</td>
</tr>
<tr>
<td>Global Markets</td>
<td>19</td>
</tr>
<tr>
<td>Patents and Research Expenditures</td>
<td>22</td>
</tr>
<tr>
<td>Comparative Edge, Obstacles to Success</td>
<td>23</td>
</tr>
<tr>
<td>Firm Location Decisions</td>
<td>24</td>
</tr>
<tr>
<td>Startup Capital</td>
<td>25</td>
</tr>
<tr>
<td>Special Case: MIT Alumni Companies in California</td>
<td>25</td>
</tr>
<tr>
<td>Special Case: MIT in Massachusetts</td>
<td>26</td>
</tr>
<tr>
<td>MIT—Its Unique History, Culture, and Entrepreneurial Ecosystem</td>
<td>28</td>
</tr>
<tr>
<td>Early Influences: The Heritage of World War II Science and Technology</td>
<td>28</td>
</tr>
<tr>
<td>Building on a Tradition</td>
<td>29</td>
</tr>
<tr>
<td>The Neighboring Infrastructure</td>
<td>31</td>
</tr>
<tr>
<td>Accelerating Upward from the Base: Positive Feedback</td>
<td>34</td>
</tr>
<tr>
<td>Technology Clusters</td>
<td>35</td>
</tr>
<tr>
<td>Other “Pulls” on Potential Entrepreneurs</td>
<td>38</td>
</tr>
<tr>
<td>A Unique Culture</td>
<td>40</td>
</tr>
<tr>
<td>“Pushes” on Entrepreneurship</td>
<td>41</td>
</tr>
</tbody>
</table>
An Evolving MIT Internal Entrepreneurial Ecosystem ................................................................. 44

Alumni Initiatives: Seminars and the MIT Enterprise Forum .................................................... 44

Case Example: Brontes Technology ......................................................................................... 47

The MIT Entrepreneurship Center ........................................................................................... 47

Classes .................................................................................................................................... 48

Academic Classes in Entrepreneurship ..................................................................................... 49

Practitioner Classes in Entrepreneurship ................................................................................ 49

Mixed-Team Project Classes ...................................................................................................... 49

Case Example: SaafWater .......................................................................................................... 50

Clubs ....................................................................................................................................... 51

From $10K to $100K and Beyond ............................................................................................. 51

Lots of Clubs ............................................................................................................................. 54

Conferences ............................................................................................................................... 55

Impact of the MIT Entrepreneurship Center and Network ..................................................... 56

Technology Licensing Office .................................................................................................... 56

Case Example: A123 Systems .................................................................................................. 59

Recent MIT Institutional Broadening and Growth ................................................................. 61

MIT Venture Mentoring Service ............................................................................................... 61

MIT Deshpande Center ............................................................................................................ 62

Case Example: Myomo ............................................................................................................... 63

MIT Sloan Entrepreneurship & Innovation MBA Program ........................................................ 64

Conclusions: Enhancing the Role of Research/Technology Universities in an Entrepreneurial Economy .................................................................................................................. 66

Appendix: Sources of Information ........................................................................................... 68

Company Database .................................................................................................................... 68

Alumni Survey ............................................................................................................................. 68

Estimation Methods ................................................................................................................... 69

References .................................................................................................................................. 72
Executive Summary

Economic Impact of MIT Alumni Entrepreneurs

Research- and technology-intensive universities, especially via their entrepreneurial spinoffs, have a dramatic impact on the economies of the United States and its fifty states. This report is an in-depth case study, carried out during the past few years, of a single research/technology university, the Massachusetts Institute of Technology, and of the significant consequences it has helped to produce for the nation and the world via its broad-based entrepreneurial ecosystem. From our extensive data collection and analyses, we conclude that, if the active companies founded by MIT graduates formed an independent nation, conservative estimates indicate that their revenues would make that nation at least the seventeenth-largest economy in the world. A less-conservative direct extrapolation of the underlying survey data boosts the numbers to 25,800 currently active companies founded by MIT alumni that employ about 3.3 million people and generate annual world revenues of $2 trillion, producing the equivalent of the eleventh-largest economy in the world.

The ultimate value of this study is to help us understand the economic impact of the entrepreneurial ventures of university graduates. We know that some universities play an important role in many economies through their core education, research and development, and other spillovers. But in order to support economic growth through entrepreneurship, universities must create programs and a culture that make entrepreneurship widely accessible to students. While MIT’s leadership in developing successful entrepreneurs has been evident anecdotally, this study—one of the largest surveys of entrepreneur alumni ever conducted—quantifies the significant impact of MIT’s entrepreneurial ecosystem that supports firm startups. And, while MIT is more unique and unusual in the programs it offers and in its historical culture of entrepreneurship, MIT provides a benchmark by which other institutions can gauge the economic impact of their alumni entrepreneurs. The report also provides numerous examples of programs and practices that might be adopted, intact or modified as needed, by other universities that seek enhanced entrepreneurial development.

Our database is from a 2003 survey of all living MIT alumni1, with additional detailed analyses, including recent verification and updating of revenue and employment figures from the 2006 records of Compustat (public companies) and Dun & Bradstreet (private companies). For further conservatism of our projections, we have deliberately excluded from our database companies in which the MIT alumnus founder had died by 2003, even if the company still survives, such as Hewlett-Packard or Intel. Even if the founder is still alive, we generally have excluded from our numbers those MIT alumni-founded companies that had merged with or been sold to other firms, such as Digital Equipment Corporation, which had peak employment of 140,000 people prior to its merger with Compaq in 1998. Nor do the database numbers include MIT alumni-founded firms that had...
closed prior to our 2003 survey. These estimates similarly ignore all companies founded by non-alumni MIT faculty or staff. Thus, we feel that our overall portrayal of MIT’s entrepreneurial impact is quite conservative. Nor do we examine in addition to these entrepreneurial spinoffs the impact of MIT-generated science and technology on the overall innovation and competitiveness of government and industries that benefit from direct and indirect transfer of scientific know-how and discoveries emerging from MIT, its faculty, staff, and graduates.

While the economic estimates we present contain some degrees of uncertainty, the trends in the numbers are clear. More entrepreneurs emerge out of each successive MIT graduating class, and they are starting their first companies sooner and at earlier ages. Over time, the number of multiple companies founded per MIT entrepreneurial alumnus also has been increasing, therefore generating dramatically increased economic impact per graduate. MIT acts as a magnet for foreign students who wish to study advanced engineering, science, and management, and a large fraction of those students remains in the United States. Well over half of the firms created by foreign students who graduate from MIT are located in the United States, generating most of their economic impact in this country.

Thirty percent of the jobs in the MIT alumni firms are in manufacturing (far greater than the 11 percent of manufacturing jobs in the United States overall) and a high percentage of their products are exported. In determining the location of a new business, entrepreneurs say the quality of life in their community, proximity to key markets, and access to skilled professionals were critical considerations, but almost all locate where they had been working or attending university, including near graduate schools other than MIT.

The study reveals that the states benefiting most from jobs created by MIT alumni are Massachusetts (for which we estimate just under one million jobs worldwide for the entire population of more than 6,900 active MIT alumni-founded, Massachusetts-headquartered companies), California (estimated at 526,000 jobs from its current approximately 4,100 MIT alumni-founded firms), New York (estimated at 231,000 jobs), Texas (estimated at 184,000) and Virginia (estimated at 136,000). Fifteen other states are likely to have more than 10,000 jobs each and only eleven states seem to have fewer than 1,000 jobs from MIT alumni companies.

As a result of MIT, Massachusetts has for many years been dramatically “importing” company founders. The estimated 6,900 MIT alumni firms headquartered in Massachusetts generate worldwide sales of about $164 billion. More than 38 percent of the software, biotech, and electronics companies founded by MIT graduates are located in Massachusetts, while less than 10 percent of arriving MIT freshmen are from the state. Not only do MIT alumni, drawn from all over the world, remain heavily in Massachusetts, but their entrepreneurial offshoots benefit the state and country significantly. Greater Boston, in particular, as well as northern California and the Northeast, broadly, are homes to the largest number of MIT alumni companies, but significant numbers of MIT alumni companies are also in the South, the Midwest, the Pacific Northwest, and in Europe. About 30 percent of MIT’s foreign students form companies, of which at least half are located in the United States. Those estimated 2,340 firms located in the U.S. but formed by MIT foreign-student alumni employ about 101,500 people.

The Types of Companies MIT Graduates Create

MIT alumni companies are primarily knowledge-based companies in software, biotech, manufacturing (electronics, instruments, machinery), or consulting (architects, business consultants, engineers). These companies have a disproportionate importance to
their local economies because they typically represent advanced technologies and usually sell to out-of-state and world markets. Their global revenues per employee are far greater than the revenues produced by the average American company. Furthermore, they employ higher-skilled as well as higher-paid employees. They also tend to have far lower pollution impact on their local environments.

An important subset of the MIT alumni companies is in software, electronics (including instruments, semiconductors, and computers), and biotech. These firms are at the cutting edge of what we think of as high technology and, correspondingly, are more likely to be planning future expansion than companies in other industries. They export a higher percentage of their products, hold one or more patents, and spend more of their revenues on research and development. (Machinery and advanced materials firms share many of these same characteristics but are not nearly as numerous as the electronics, software, and biotech companies.)

More than 900 new MIT alumni companies were founded each year during the decade of the 1990s. But the bulk of total MIT-generated employment results from the estimated 800 companies of 1,000 or more employees who have created nearly 85 percent of the jobs. Not surprisingly, most of the larger companies have been in existence for some time, but many younger entrepreneurs have built sizable companies in a short period of time. One in six of the companies founded by a graduate out of school fifteen years or less already has 100 or more employees.

The MIT Entrepreneurial Ecosystem

Rather than any single or narrow set of influences, the overall MIT entrepreneurial ecosystem, consisting of multiple education, research, and social network institutions and phenomena, contributes to this outstanding and growing entrepreneurial output. The ecosystem rests on a long MIT history since its 1861 founding and its evolved culture of “Mens et Manus,” or mind and hand. The tradition of valuing useful work resulted in the development of strong ties with industry, including encouraging faculty consulting and even faculty entrepreneurship since before the beginning of the twentieth century. Over the years, the increasingly evident MIT entrepreneurial environment has attracted entrepreneurship-inclined students, staff, and faculty, leading to a strong positive feedback loop of ever-increasing entrepreneurial efforts.

Alumni initiatives in the 1970s appear to be the first direct institutional moves to encourage entrepreneurship, leading to the establishment of the now-worldwide MIT Enterprise Forum. Since its beginning, the Cambridge, Mass., chapter alone has helped nurture more than 700 young companies, with equivalent numbers across the rest of the country. Beginning in 1990, the MIT Entrepreneurship Center has crystallized these efforts by launching nearly thirty new entrepreneurship courses at MIT, and by assisting in the formation and growth of a large number of related student clubs. The resulting increase in networking among students, and between them and the surrounding entrepreneurship and venture capital community appears in survey results to be the primary MIT-related factor influencing the growth of new-company formation.

Classes taught by discipline-based academics and experienced, successful entrepreneurs and venture capitalists have generated an effective blend for learning both theory and practice. Mixed-team project classes, consisting of both management students and engineers and scientists, have had great impact on MIT students in their understanding of the entrepreneurial process, have initiated their exposure to and engagement with real-world new enterprises, and have influenced the subsequent founding of many new companies. Student-run activities such as the MIT $100K Business Plan Competition have moved numerous students, often with faculty as team members, to develop their ideas to the point of public scrutiny. At least 120 companies have been started by participants in these student-run competitions.
The MIT Technology Licensing Office has consistently led the country’s universities in licensing technology to startup firms, licensing to 224 new companies in just the past ten years. The TLO also has brought its experience and knowledge into active engagement with MIT students, faculty, and alumni.

In recent years, creation of formal MIT institutions focused on encouraging entrepreneurship has accelerated. In 2000, the Venture Mentoring Service was begun to help any MIT-related individual—student, staff, faculty, alumnus/a—who was contemplating a startup. It already has seen more than eighty-eight companies formed by those it has counseled.

The Deshpande Center for Technological Innovation was initiated in 2002 to provide small research grants to faculty whose ideas seemed especially likely to be able to be commercialized. In its first five years, the Deshpande Center has funded eighty faculty research projects. Fifteen spinout companies already have been formed from these projects.

In 2006, the MIT Sloan School of Management created a new Entrepreneurship & Innovation track within its MBA program to provide intensive opportunities for those students who seem dedicated to an entrepreneurial life. It is too soon to know what outcomes this focused approach will produce, but about 25 percent of incoming MBA candidates now are enrolling in this concentration and initial students already have engaged in numerous company-building activities and have won important university business plan competitions.

Beyond the MIT influences on firm formation, 85 percent of the alumni entrepreneurs reported in the survey data that association with MIT had significantly helped their credibility with suppliers and customers. Fifty-one percent of the entrepreneurs also felt that their association with MIT helped in acquiring funding.

All of these forces—from initial orientation and culture to all-encompassing clubs and activities to now-concentrated educational opportunities—contribute to building and sustaining the MIT entrepreneurial ecosystem. That system has been uniquely productive in helping to create new firms that have had impressive economic impact.
Entrepreneurial Impact: The Role of MIT

The Role of MIT Alumni Companies in the U.S. Economy

For some time, anecdotes and research have indicated significant entrepreneurial impact from MIT. In 2003, along with professional staff from MIT, the authors set about to attempt to quantify through surveys and research the actual economic impact of entrepreneurship among MIT alumni. The results presented here—the first disclosure of this research—are supplemented with some detail on the history, institutions, and culture that have combined to influence entrepreneurship at MIT.

In 2001, MIT sent a survey to all 105,928 living alumni with addresses on record. MIT received 43,668 responses from alumni. Of these, 34,846 answered the question about whether or not they had been entrepreneurs. A total of 8,179 individuals (23.5 percent of the respondents) indicated that they had founded at least one company. In 2003, we developed and sent a survey instrument focused on the formation and operation of these firms to the 8,044 entrepreneur respondents for whom we had complete addresses. Of this group, 2,111 founders completed surveys. The database reported on in this report was created from these surveys, as well as additional detailed analyses, including verification and updating of revenue and employment figures from the 2006 records of Compustat (public companies) and Dun & Bradstreet (private companies). The Appendix provides further details on the survey and estimation methods.

Based on our extensive data collection and analyses, we conclude that, if the active companies founded by MIT graduates formed an independent nation, conservative estimates indicate that their revenues would make that nation at least the seventeenth-largest economy in the world. A less-conservative direct extrapolation of the underlying survey data boosts the numbers to some 33,600 total companies founded over the years by living MIT alumni, of which 25,800 (76 percent) still exist, employing about 3.3 million people and generating annual worldwide revenues of $2 trillion, the equivalent of the eleventh-largest economy in the world.

For conservatism of our projections, we have deliberately excluded from the database companies in which the MIT alumnus founder already had died, even if the company still survives, such as Hewlett-Packard or Intel. If the founder is still alive, we have excluded from our database those MIT alumni-founded companies that had merged with or been sold to other firms prior to 2003, such as Digital Equipment Corporation, which had peak employment of 140,000 people prior to its merger with Compaq in 1998. Nor do the numbers include MIT alumni-founded firms that had closed prior to our 2003 survey. These estimates similarly ignore all companies founded by non-alumni MIT faculty or staff. In addition, we do not examine the impact of MIT-generated science and technology on the overall innovation and competitiveness of government and industry beyond alumni-founded firms. Clearly, entrepreneurship likely has benefited from additional spillovers from the scientific and non-scientific advances emerging from MIT, its faculty, staff, and graduates. Thus, we attempt to portray only an aspect of MIT’s entrepreneurial impact.

Companies founded by MIT alumni have a broad footprint on the United States (and the globe). While more than a quarter of these active companies (projected to be 6,900) have headquarters in Massachusetts, nearly 60 percent of the MIT alumni companies are located outside the Northeast. These companies have a major presence in the San Francisco Bay Area (Silicon Valley), southern California, the Washington-Baltimore-Philadelphia belt, the Pacific Northwest, the Chicago area, southern Florida, Dallas and Houston, and the industrial cities of Ohio, Michigan, and Pennsylvania.
As shown in Table 1, relatively few but larger companies account for a substantial proportion of the total sales and employment of MIT alumni-founded companies. We estimate that the 796 largest current MIT alumni companies (about 2 percent of the total estimated companies)—those with employment of 1,000 or more—account for more than 80 percent of total sales and 70 percent of employment of all the MIT alumni-founded firms. Most of these larger firms are quite old. But many young graduates have managed to build companies of impressive size in a short period of time. We estimate that 213 companies with a founder who graduated in the last thirty years (and fifteen with founders who graduated in the last fifteen years) have 500 or more employees. Of these 213 younger-but-larger companies, about 28 percent are in software, 10 percent are in telecommunications, and 21 percent are in electronics. Of the approximately 14,700 firms founded by MIT graduates from the last fifteen years, 10 percent already have 100 or more employees. This compares to 12 percent for founders out fifteen to thirty years, and 13 percent for founders out thirty to fifty years.

Two-thirds of the MIT alumni companies over the entire sixty-year span of our data have been co-founded, with the size of the founding group steadily increasing from 2.3 in the 1950s to 3.3 in the 2000s. We also have found consistency over all these years in the attributed sources of the ideas for these new enterprises. On average, two-thirds of the founders claim that the ideas for the firm came from industry work experience, about 15 percent from networking, and about 10 percent from research.

**Additional Trends over the Decades**

**Growth in Numbers**

We estimate that 2,900 currently active companies were founded during the 1980s and as many as 9,950 companies were founded during the 1990s, of which 5,900 are still active. More than 5,800 companies were created between 2000 and 2006. For each decade (using our linear projection), Figure 1 shows the estimated yearly growth over the past fifty years of the number of “first firms”

![Figure 1](image-url)
founded by all MIT alumni. **New company formation by MIT graduates is accelerating.** (We omit from this figure but will later present our evidence on the second, third, and more companies generated by many of the MIT alumni over their entrepreneurial careers.)

Further evidence on the acceleration of MIT alumni entrepreneurship through the past five decades is obvious in Figure 2, where we limit ourselves for consistency to just the Bachelor’s degree recipients who responded to the limited survey of MIT alumni that was done in 2003. The figure shows clearly that the cohort of Bachelor’s degree graduates from each successive decade has been forming more new first companies.³

**More Diverse Entrepreneurs**

We find evidence of significant shifts in demographics among MIT entrepreneurs, particularly on gender and citizenship. The numerical growth of women entrepreneurs appears to mirror the growth in number of women graduating from all levels at MIT, rising from just over ten female graduates per year (1 percent) in the 1930s to 43 percent of undergraduates and 30 percent of the graduate student population in 2006. Women alumnae lag their male classmates (but slowly are catching up) in the proportion that become entrepreneurs. Women founders start appearing in the 1950s and, as shown in Figure 1, grow to 6 percent of the reporting sample by the 1990s, and are up to 10 percent by the 2000s.

---

³ The MIT undergraduate class grew from about 900 per year in the 1950s to about 1,050 in subsequent decades. Graduate school enrollments have grown considerably, as well, over the same time period, including, in particular, the institutionalization of the MIT Sloan School of Management in 1952. In many of our analyses, we took these size changes into account via normalization per 1,000 alumni at each decade. But these normalized analyses did not alter any of the underlying trends reported here.
Alumni who were not U.S. citizens when admitted to MIT founded companies at different (usually higher per capita) rates relative to their American counterparts, with at least as many remaining in the United States as are returning to their home countries. Figure 1 indicates that non-U.S. citizens begin slight visibility as entrepreneurs in the 1940s, grow steadily to 12 percent of the new firm formations during the decade of the 1990s, and are up to 17 percent by the 2000s.

About 30 percent of the foreign students who attend MIT found companies at some point in their lives. This is a much higher rate than for U.S. citizens who attend MIT. We assume (but do not have data that might support this) that foreign students are more inclined from the outset to become entrepreneurs, as they had to seek out and get admitted to a foreign university, taking on the added risks of leaving their families and their home countries to study abroad. (MIT has only its one campus in Cambridge, Mass., and, despite collaborations in many countries, does not operate any degree program outside of the United States.) We estimate that about 5,000 firms were started by MIT graduates who were not U.S. citizens when they were admitted to MIT. Half of those companies created by “imported” entrepreneurs, 2,340 firms, are headquartered in the United States, generating their principal revenue ($16 billion) and employment (101,500 people) benefits here.

As shown in Table 2, an even higher fraction of the foreign student-founded manufacturing firms, which usually have the greatest economic impact, are located in the United States. The largest non-U.S. locations of alumni firms founded by foreign students are in Europe and Latin America. More than 775 MIT foreign-alumni businesses are in Europe, most of which are in software and consulting. The greatest numbers of these firms are in England, France, and Germany. Latin America has an estimated 500 firms, most of which are in Mexico, Brazil, and Venezuela. Asia has 342 firms, of which the largest numbers are in China, Japan, and India.

As is true of all the alumni-founded firms, many of these now are sizable businesses, but most are small; the median number of employees of those founded by foreign students in Europe and Asia is eighteen employees and the median revenues are a little more than $1 million. Almost three-quarters of these businesses are started by alumni with MIT graduate degrees; not too surprising, as historically MIT has had few undergraduates from outside of the United States. About half of the American founders have advanced degrees from MIT.

Of the U.S.-located companies founded by MIT’s foreign students, 66 percent were started in the 1990s or 2000s. European alumni started 36 percent of the 2,340 U.S.-located firms and alumni from Asian countries started 28 percent of them. This

<table>
<thead>
<tr>
<th>Location</th>
<th>Total</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>2,340</td>
<td>673</td>
</tr>
<tr>
<td>Europe</td>
<td>790</td>
<td>51</td>
</tr>
<tr>
<td>Latin America</td>
<td>495</td>
<td>63</td>
</tr>
<tr>
<td>Asia</td>
<td>342</td>
<td>43</td>
</tr>
</tbody>
</table>

Table 2
Estimated Number of Companies Founded by “Foreign” MIT Alumni
The Role of MIT Alumni Companies in the U.S. Economy

The geographic source distribution of foreign-alumni entrepreneurs will no doubt shift as Asians become a larger fraction of the MIT foreign-student population.

Younger Entrepreneurs

The tendencies shown in Figures 1 through 4 are clear: More entrepreneurs emerge out of each successive MIT graduating class, and they start their first companies sooner and at earlier ages. To illustrate this, in Figure 3 we display for Bachelor’s degree graduates only how many companies were founded by each decade’s cohort group as a function of the number of years following their MIT graduation. During each successive decade, the cohort of graduating alumni got started in its entrepreneurial behavior sooner (i.e., the cumulative number of companies rises much faster in terms of years after graduation) than the preceding decade’s cohort.

Figure 4 shows three frequency distributions of the ages of MIT alumni first-time entrepreneurs for firms founded during and prior to the 1970s, for those founded in the 1980s, and for those founded in the 1990s. Note the general shifts in the three curves over the years. The distributions show that the more recent entrepreneurs include many more from the younger age brackets, as well as slightly more from the late forties and fifties age brackets. During and prior to the 1970s, 24 percent of the first-time entrepreneurs were under thirty years of age; during the 1980s that number grew to 31 percent; in the 1990s, 36 percent of the founders were under thirty. During and prior to the 1970s, 30 percent of the first-time founders were older than forty years of age; during the 1980s, 28 percent were older than forty; and, in the 1990s, 35 percent were older than forty. More than half of all MIT alumni companies now are founded within ten years of the time the founder graduates from MIT; one-quarter of the companies are founded within six years of graduation. The median age of first-time entrepreneurs gradually has declined from about age forty (1950s) to about age thirty (1990s). Correspondingly, the average time lag
between graduation and first firm founding for alumni from the more recent decades dropped to as low as four years from graduation during the “Internet bubble” years of the 1990s.

To check on possible industry effects, we separated out those who had formed software companies. Figure 5 shows that the majority of software founders over all the decades of our study are age thirty or younger and the majority of non-software industry founders are below age thirty-five the year they found their first firms. But, not shown in this report, the increase in software entrepreneurship in recent years does not statistically account for the continuing decline in the average entrepreneurial age at time of first company formation.

We support the above arguments with the data in Table 3, demonstrating that the ages of first-time MIT alumni entrepreneurs have been getting younger each decade, whether male or female, U.S. or
The Role of MIT Alumni Companies in the U.S. Economy

Table 3
Median Age of First Firm Founders

<table>
<thead>
<tr>
<th>First Firm Founders</th>
<th>Decade of Graduation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1950s</td>
</tr>
<tr>
<td>All</td>
<td>40.5</td>
</tr>
<tr>
<td>Non-U.S. Citizens</td>
<td>38.0</td>
</tr>
<tr>
<td>Women</td>
<td>42.0</td>
</tr>
</tbody>
</table>

foreign citizen. (The big drop in the 1990s no doubt reflects the fact that many more graduates from the 1990s will form companies later, moving the average age upward to some extent.)

Serial Entrepreneurs

To this point, we have focused primarily on the vast number of MIT alumni who have founded their first enterprises. Yet the phenomenon of MIT graduates embarking on careers of repeat or “serial” entrepreneurship appears to be growing over time. Using only the limited data from the 2003 survey results, without any scaling adjustment, Figure 6 shows the number of first firms, second firms, and third (and more) firms by their founding year. By definition, “first-time” firms are the most prevalent, and the number of first firms founded increases over the years. Separate from any other trends, we expect this increase due to the fact that each year adds another year of graduates with the potential for entering entrepreneurship. Table 4 presents, by their decade of graduation, the number of entrepreneurs founding one firm (the top line) up to five or more firms (the high in the database is eleven firms founded by an alumnus). The bottom row, labeled “Percent Repeat,” is the percentage of founders from each decade of MIT graduates who have started more than one firm. Across the decades, MIT alumni founders who have founded multiple startups have grown from 33 percent of those who graduated in

Table 4
One-Time and Repeat MIT Founders by Decade of Graduation (percent)

<table>
<thead>
<tr>
<th>Total Number of Firms Founded</th>
<th>1930s</th>
<th>1940s</th>
<th>1950s</th>
<th>1960s</th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
<th>2000s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67%</td>
<td>61%</td>
<td>56%</td>
<td>54%</td>
<td>48%</td>
<td>57%</td>
<td>61%</td>
<td>59%</td>
</tr>
<tr>
<td>2</td>
<td>0%</td>
<td>11%</td>
<td>21%</td>
<td>20%</td>
<td>23%</td>
<td>22%</td>
<td>23%</td>
<td>28%</td>
</tr>
<tr>
<td>3</td>
<td>0%</td>
<td>9%</td>
<td>10%</td>
<td>11%</td>
<td>16%</td>
<td>11%</td>
<td>9%</td>
<td>9%</td>
</tr>
<tr>
<td>4</td>
<td>11%</td>
<td>8%</td>
<td>7%</td>
<td>7%</td>
<td>6%</td>
<td>5%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>5+</td>
<td>22%</td>
<td>11%</td>
<td>7%</td>
<td>9%</td>
<td>7%</td>
<td>5%</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Percent Repeat</td>
<td>33%</td>
<td>39%</td>
<td>44%</td>
<td>46%</td>
<td>52%</td>
<td>43%</td>
<td>39%</td>
<td>41%</td>
</tr>
</tbody>
</table>
the 1930s to 52 percent of those who graduated in the 1970s. The decrease in the Table 4 entry percentage from the 1980s on is likely due to the fact that many of the more recent graduates have not yet had time to start a second (or more) firm but certainly may do so in the future.

The MIT alumni entrepreneurs who eventually found multiple companies differ substantially from “single-firm-only” entrepreneurs, and their companies are quite different, too. For example, proportionately more of the repeat founders are not U.S. citizens and a slightly higher proportion of the repeat entrepreneurs hold Master’s degrees. Relative to the repeat entrepreneurs, those who found only one company throughout their lives are older when they establish their sole company and have a longer lag from graduation to that founding. Repeat/serial entrepreneurs enter entrepreneurship much sooner, which likely reflects their own strong entrepreneurial tendencies while also giving them more time to start subsequent firms.

Table 5, directly from our limited 2003 sample, contains economic impact indicators of the one-time and repeat entrepreneurs in terms of firms founded, revenues, and employees. The representative MIT alumni entrepreneur founds 2.07 companies over his lifetime. We see in Table 5 that repeat entrepreneurs have a substantial economic impact relative to the percentage of total entrepreneurs, accounting for about three times the total company revenues and employees as the single-firm founders. Thus, a third observed trend is that, over time, the number of multiple companies founded per MIT entrepreneurial alumnus has been increasing, with dramatically increased economic impact per graduate.

4. This statistic uses the total number of firms each entrepreneur claimed to have started. For the remainder of the analyses, we use the number of firms for which they listed the company names and founding dates in the 2003 survey. The listings are more reliable and conservative but were capped by the survey instrument at five.
The Role of MIT Alumni Companies in the U.S. Economy

Table 5.
Economic Impact of One-Time and Repeat Entrepreneurs (from limited sample only)

<table>
<thead>
<tr>
<th>Category of Entrepreneur</th>
<th>One-Time Entrepreneurs</th>
<th>Repeat/Serial Entrepreneurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sales (in '000 $2006)</td>
<td>$9,876,900</td>
<td>$29,190,000</td>
</tr>
<tr>
<td>Total Employment</td>
<td>111,915</td>
<td>344,208</td>
</tr>
<tr>
<td>Total # of Firms Founded</td>
<td>1,086</td>
<td>3,193</td>
</tr>
<tr>
<td>Total Founders in the Sample</td>
<td>1,086</td>
<td>981</td>
</tr>
<tr>
<td>Percentage of Entrepreneurs</td>
<td>52.5%</td>
<td>47.5%</td>
</tr>
<tr>
<td>Percentage of Firms</td>
<td>25.4%</td>
<td>74.6%</td>
</tr>
<tr>
<td>Percentage of Total Revenues</td>
<td>25.3%</td>
<td>74.7%</td>
</tr>
<tr>
<td>Percentage of Total Employment</td>
<td>24.5%</td>
<td>75.5%</td>
</tr>
</tbody>
</table>

MIT Founders and MIT Course Majors

More MIT founders—more than 20 percent of the total—come from the Institute’s electrical engineering and computer science programs (the two are linked in the same MIT department) than from any other department. Other programs heavily represented among the founders are management; mechanical, chemical, and civil engineering; architecture; physics; and aeronautics.

Over the years, an interesting shift has occurred, reflecting underlying change at MIT in the course majors taken by company founders. More than 65 percent of the founders who graduated more than fifty years ago were engineering majors. Only 44 percent of company founders who graduated in the last fifteen years are engineers, while 32 percent are from the social sciences/management departments. We estimate the total number of MIT alumni companies founded by living engineering majors as 17,090 compared with 9,100 companies founded by science majors and 6,860 companies by management majors, certainly affected by the relative sizes of the graduating populations.

Some correlation, but no predictable connection, exists between the founder's major and the type of company. For example, only 10 percent of alumni-created biotech and medical companies are founded by life-science graduates; 59 percent are founded by engineers. Social science and management graduates account for 9 percent of electronics firms, 10 percent of other manufacturing firms, and 20 percent of software companies, while engineering graduates account for 46 percent of the companies in finance and 45 percent of the management consulting firms. These differences reflect, in part, the additional degrees of the MIT alumni, whether from MIT or from other universities, and/or the backgrounds of their co-founders.

We normalized the number of entrepreneurs from each MIT school (MIT contains five schools), using the numbers graduating in each decade as our bases for normalization. Despite increased participation over time from science graduates, the percentage of them who become entrepreneurs is still the smallest of all study areas, over essentially the entire time studied. The data show that, proportionately, from 50 percent to 100 percent more MIT engineering graduates than science alumni eventually have become entrepreneurs. Management graduates overall seem to be at least as inclined proportionately to become entrepreneurs as are MIT
Table 6
Proportion of Founders from Three Selected Academic Areas of MIT
(percent of all MIT alumni companies founded during the decade)

<table>
<thead>
<tr>
<th>First Firm Founders</th>
<th>Decade of First Firm Founding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1950s</td>
</tr>
<tr>
<td>EE and CS degrees</td>
<td>20.4%</td>
</tr>
<tr>
<td>Life Sciences degrees</td>
<td>0.0%</td>
</tr>
<tr>
<td>Management degrees</td>
<td>16.7%</td>
</tr>
</tbody>
</table>

Engineering graduates. Architecture alumni are, on a proportional basis, perhaps surprisingly, the most likely among graduates of all the MIT schools to strike out on their own. But this no doubt reflects a dominant “industry” structure of large numbers of small architectural practices, with relatively frequent changes in partnerships (i.e., new “firms”).

Table 6 provides further details on the trends in three selected academic areas of MIT: electrical engineering and computer science (EECS), biology/life sciences, and management. EECS has, by tradition, been the largest MIT department and the most evident home of its entrepreneurial offshoots. Biology/life sciences is an up-and-coming “technology change area,” and we wish to portray its entrepreneurial inclinations. Management appears to have established itself as a common ground for entrepreneurial interest development and we want to examine how deeply rooted are these indicators.

The data show that the percentage of founders graduating with degrees in biology/life sciences has indeed increased over the years, but appears to have leveled off in recent decades at around 5 percent. The percentage of founders who are EECS majors remains the highest at slightly more than 20 percent, and those with management degrees hover around 15 percent. Both EECS and management appear to be relatively stable in their proportionate supply of entrepreneurs over the decades.

Industry Composition and Effects

Table 7 shows an estimated industry breakdown of MIT alumni companies by number of firms, sales, and employment. MIT alumni found companies in a diverse array of industries, although they do tend to cluster in certain sectors. About 3,300 companies, employing an estimated total of 436,100 people, are in electronics, which (as used here loosely) includes computers, semiconductors, instruments, telecommunications equipment, and electrical machinery and appliances. These electronics firms make up 13 percent of the MIT alumni companies. All told, manufacturing firms make up 13 percent of the MIT alumni companies, 21 percent of total employment, and 6 percent of total sales. In the United States as a whole, manufacturing accounts for less than 11 percent of total employment. Naturally, company size varies according to industry. Although

5. Not all electronics firms are in manufacturing. Some, for example, are in IC design (computer companies and telecommunications also were grouped with electronics). The estimate depends on how we calculate what is truly manufacturing. The Standard Industrial Classification (SIC) codes (which are admittedly imperfect) of the companies indicate 13 percent with manufacturing codes. However, the entrepreneurs’ industry self-reports suggest that manufacturing constitutes as much as 31 percent. The truth is probably between these two estimates at around 20 percent, much higher than for the United States as a whole, as we would expect for graduates of a technical university.
their cumulative impact is significant, the median size in every industry is quite small, reflecting the overall national experience and the large number of young firms.

Firms in software, electronics (including instruments, semiconductors, and computers), and biotech form a special subset of the MIT alumni companies. These high-technology firms (1) spend more of their revenues on research and development, (2) are more likely to hold one or more patents, and (3) tend to export a higher percentage of their products. They are more likely than companies in other industries to provide the bases for long-term economic growth. Together, firms in these three industries account for one-third of the employment in all MIT alumni companies; electronics and instrument firms alone account for more than 13 percent.

The expansion plans of the companies we surveyed form an interesting “leading indicator,” pointing to growth prospects by industry. More than 30 percent of the firms in chemicals, aerospace, and biotech are planning to expand. They are followed closely by telecommunications and consumer products companies.
Global Markets

In any regional economy, firms that sell out-of-region play the major role in driving economic growth because, as these firms grow in total revenues, they also are growing in local employment, and they create markets for utilities, service firms, retailers, and other local-market businesses. MIT alumni companies have a disproportionate importance to their local economies because so many of them are manufacturing, biotech, and software firms (48 percent of the employment of MIT alumni companies) that tend to compete in and sell to national and world markets. Overall, 54 percent of company sales are to out-of-state markets; 13 percent of total sales come from goods or services sold by U.S. firms abroad. Figure 7 shows these percentages by industry. For electronics, chemical, machinery, biotech, software, and management consulting firms, 65 percent of sales are out-of-state. The only companies that have in-state sales amounting to 50 percent or more of total revenues are architects, finance companies, publishing, and law firms.

Across all industries, exports (outside of the United States by U.S.-based firms) account for 13 percent of the sales revenues of MIT alumni companies. Exports are slightly higher for biomedical, machinery, and electronics firms (more than 20 percent). Companies in all other industries have an average export share of just under 10 percent. These high-tech, high-growth industries clearly depend on foreign as well as domestic markets.

Figures 8 and 9 present the distributions by industry of the 2003 survey responses. Among manufacturing industries, electronics has held its own for six decades as a major opportunity area for MIT alumni entrepreneurs. On the services side, software firms have grown strikingly as a percentage of firms founded since the 1950s. Also of note is the rapid
Figure 8
Changing Industry Mix of Manufacturing Startups (percentage)

Figure 9
Changing Industry Mix of Services Startups (percentage)
growth since the 1960s of ventures in financial services and management/financial consulting, no doubt reflecting both the market opportunities as well as the growth of the number of MIT Sloan Master’s degree graduates during this period. Some of the trends may be attributable to changes in the size of certain departments relative to the rest of MIT (for example, architecture).

Figure 8 shows the trends over sixty years in the mix of new manufacturing companies being formed by MIT grads, the dominance of electronics firms, and an increase in drug and biomedical firms. Mirroring similar trends in the overall United States and world economies, the percentage of MIT alumni manufacturing firms has been slowly decreasing over the decades, as shown in Figure 10. From a high of about 20 percent manufacturing firms in the 1950s, about 10 percent of the firms founded in the 1990s and 2000s were manufacturing firms. On average over the decades, 13 percent of the firms founded by MIT alumni are manufacturing firms. But they employ about 30 percent of the total employees of all MIT alumni firms. An interesting observation from Table 2 shown earlier in this report is that the U.S.-located companies founded by MIT foreign-student alumni include more than 28 percent in manufacturing. The overseas-located firms established by foreign alumni include less than 10 percent in manufacturing.
Patents and Research Expenditures

In all, between nearly 30 percent up to more than 40 percent of the surveyed firms in aero/astro, biomed, chemicals, electronics, and machinery hold at least one patent. Consistent with their reputations as the two premier technology locations in the country, as shown in Figure 11, California and Massachusetts firms are more likely to hold patents than are their colleagues in the same industries in other states. The companies that hold patents average around twenty-six patents each. Since larger companies are more likely to have had the time and legal resources to generate and protect intellectual property portfolios, larger companies are more likely to hold patents (59 percent of companies with 500 or more employees hold at least one patent, compared to only 16 percent of companies with fewer than fifty employees). The larger companies also hold more patents (sixty-four per company for those with 500 or more employees versus only 0.78 for those with fewer than fifty workers).

Aerospace, biotech, electronics, chemicals, and software firms tend to report spending more on R&D, as shown in Figure 12. The average for all surveyed MIT alumni companies is 24 percent of total revenues spent on research and development, whereas software companies spend 29 percent. In contrast, the average R&D spending for all U.S. firms is estimated by the National Science Foundation to be 2.6 percent of GDP in 2006, demonstrating rather dramatically the extraordinary scientific and technological base of the MIT alumni firms. Average MIT companies’ spending on marketing is 18 percent of revenue.
### Competitive Edge, Obstacles to Success

The recent survey of MIT alumni entrepreneurs has generated some interesting insights into these knowledge-based companies and what gives them a competitive advantage. The survey listed competitive factors and asked respondents to rank each of them in importance. The most frequently cited factors perceived as vital to competitive advantage were:

1. superior performance,
2. customer service/responsiveness,
3. employee enthusiasm,
4. management expertise, and
5. innovation/new technology—all ahead of product price.

Although price is not unimportant (it is hard for a company to compete if its price is unreasonable), if a startup has a cutting-edge product with outstanding performance and good customer service, it reasonably can charge a premium.

In the aerospace industry (where government is the major client), price is the second-most important factor (behind superior performance). Price is least important to finance and consulting firms. Time to market is particularly important in electronics and instruments, software, and aerospace, and least important in management consulting and finance. Innovation, new technology, and time to market are particularly important to founders who graduated in the last fifteen years.

Eighty-five percent of the alumni entrepreneurs reported association with MIT as having helped boost their credibility with suppliers and customers. Fifty-one percent of the entrepreneurs also felt that their association with MIT helped in acquiring funding. Had we studied alumni entrepreneurs from Stanford University, Cal Tech, or other research-intensive institutions,
The Role of MIT Alumni Companies in the U.S. Economy

Government regulation mattered most to aerospace, chemical, and energy firms, reflecting the role of the government in defense procurement, environmental regulation, and utility regulation. Government regulation made much less difference to software and publishing companies and to company founders who graduated in the last fifteen years relative to their older counterparts.

**Firm Location Decisions**

Almost all founders (89 percent) started their companies in the general location in which they were living at the time. The largest fraction of these founders (65 percent) indicated that they were living there because this was where they had been employed, and 15 percent indicated that they were living there because that location was where they attended university, which often was MIT and, in other cases, another graduate school. When asked what factors influenced the location of their companies, the most common responses (in order) were: (1) where the founders lived, (2) network of contacts, (3) quality of life, (4) proximity to major markets, and (5) access to skilled professional workers (engineers, technicians, and managers). Taxes and the regulatory environment were rated as less-important factors for most industries. High-tech startups are highly dependent on the availability of skilled professionals to build reliable, high-quality, innovative products. The companies locate where these professionals like to live.

Within the United States, the development of Silicon Valley and other entrepreneurial locations in California is shown in Figure 13 by the shift toward about 22 percent of MIT graduates starting their companies there, while still having about 26 percent locating in Massachusetts. New York and Texas are home to about 8 percent of the firms in total, slightly increasing over the years, leaving about 45 percent of the alumni-formed firms being located in the other forty-six states.

MIT alumni firms in the high-growth, high-tech industries (software, electronics, biotech) are particularly likely to locate in California or Massachusetts, especially in the premier technology regions of Silicon Valley and Greater Boston. These two states account for 66 percent of all MIT alumni firms.
electronics firms, 62 percent of software firms, and 62 percent of drug and medical firms. By contrast, they are host to only 36 percent of firms in all other industries.

**Startup Capital**

Most MIT alumni companies start with funds from the founder's personal savings or by re-investing cash flow, as shown in Figure 14. Personal savings was the primary source determined in earlier studies, as well (Roberts, 1991, pp.124–159). Little differences generally exist in the funding patterns across industries or regions of the country, with but a few interesting exceptions. Entrepreneurs' dependence on personal, family and friends, and informal investors is not just an MIT-related phenomenon, but seems to always have been true both in the United States and globally. Strategic corporate partners are important to electronics, machinery, and chemical firms. Venture capitalists are important to software, electronics, and biotech firms, as well as to chemicals and materials firms. In none of these cases, however, were these alternate sources more important at the outset than the founders’ own savings. Although venture capital was not a major source of initial or even later funding for smaller firms, it was important for companies that grew to fifty or more employees, and was even more significant for companies that achieved 500 or more workers.

**Special Case: MIT Alumni Companies in California**

We estimate that California has the head offices of 4,100 MIT alumni firms, which employ 526,000 people worldwide and have $134 billion in sales. The 2,675 MIT alumni firms we project for northern California alone account for the greater part of the MIT presence in California—$78 billion in worldwide sales and worldwide employment of 322,100. Total employment of MIT alumni companies in Silicon Valley alone is estimated at just over 260,000—about half of total California employment of MIT alumni companies. Of this number, some 135,200 work in manufacturing and 75,500 in electronics.
A 1990 study by the Chase Manhattan Bank identifies 176 MIT-founded companies just in northern California (the Silicon Valley area), employing more than 100,000 with aggregate sales topping $20 billion. The growth over the fifteen years since that report has been impressive, perhaps attributable in part to a 1990 underestimation of the number and size of the MIT alumni firms. Chase Manhattan notes that 1924 MIT graduate Frederick Terman, former dean of engineering at Stanford University, has been acknowledged as the “father of Silicon Valley.” Other MIT figures in Silicon Valley’s past are William Shockley ’36, who co-invented the transistor, won the Nobel Prize, and founded Shockley Semiconductor Laboratory, which gave birth to the semiconductor industry; Intel co-founder Robert Noyce ’54, who devised the integrated circuit; William Hewlett, also a 1936 MIT graduate who co-founded Hewlett-Packard; and Robert Swanson ’69, who co-founded Genentech, the world’s first biotechnology company. Due to their deaths prior to 2003, none of these individuals or their firms was included in the survey database.

Well over half of the current sales and employment of California MIT alumni companies are in electronics and instruments, but more than $1 billion in sales are estimated to be in software and biotech. The region’s largest MIT alumni firms include Hewlett-Packard, Intel, National Semiconductor, 3Com, Qualcomm, Tandem Computer, Raychem, Cirrus Logic, Lam Research, Genentech, and Symantec.

Special Case: MIT in Massachusetts

An estimated 6,900 MIT alumni companies are headquartered in Massachusetts. The estimated sales of these companies—$164 billion—represent 26 percent of the sales of all Massachusetts companies. Worldwide employment of these 6,900 companies is nearly one million, with a substantial share of these jobs spread across the United States. MIT alumni companies in Massachusetts are located primarily throughout its eastern region.

However, these numbers understate the impact of MIT alumni companies on Massachusetts. In one industry after another, these companies represent cutting-edge technologies in their fields. Historical examples include Raytheon in missile and guidance systems; ThermoElectron in instruments and environmental technology; Lotus Development (now part of IBM, so not included in our impact estimates), Medical Information Technology, and Progress Software, all in software; Analog Devices and Analogics in integrated circuits and electronics devices; A123 Systems and American Superconductor in advanced materials; Teradyne in testing equipment for electronic components; M/A Com in microwave technology; BBN in electronics and networking; Genzyme, Biogen, and Alpha-Beta in biotechnology; Bose in acoustic systems; and AVID in video conferencing. Together, these leading companies provide a substantial part of Massachusetts’ high-tech environment, helping to attract highly skilled professionals and other firms to the state.

One reason MIT is so important to the Massachusetts economy is that, without MIT, most of these companies never would have been located in Massachusetts. Most of the MIT alumni companies in Massachusetts were founded by former students who came to the state to attend MIT, liked what they saw, settled down, and eventually started their companies in Massachusetts. Less than 10 percent of MIT undergraduates grew up in the state, but approximately 31 percent of all MIT alumni companies are located in Massachusetts. In the last five years, more than 37 percent of the newly founded MIT alumni companies in Massachusetts.

MIT attracts some of the brightest young people in the country (and the world); many of them like the Boston area and choose to stay there. As just one example, the late Alex d’Arbeloff ’49 came to MIT from Paris just after World War II. His first job after graduation was in New York, but he chose to come back to Boston, where eleven years later d’Arbeloff and his MIT undergraduate classmate Nick DeWolf...
‘49 started an electronic testing equipment company in DeWolf’s home. When they outgrew the house, they rented space in downtown Boston because they liked living on Beacon Hill and wanted to walk to work. Today, Teradyne has more than a billion dollars in revenues and still is located in the Boston area. Another MIT founder located his company north of Boston so he could have easy access both to downtown and, on weekends, to the Maine coast and the New Hampshire mountains. These stories underscore the critical importance of the fact that scientifically oriented entrepreneurs like living in the Boston area. Absent the symphony, the parks, the ocean, MIT and other universities, the art museums, and the other cultural and sports attractions that make Boston unique, the city would likely fail to hold these entrepreneurs and the regional economy would grow more slowly or shrink.

Another advantage of locating in Massachusetts is the proximity to MIT and other Boston-Cambridge-area universities. When asked the importance of various location factors, Massachusetts firms ranked access to MIT and other universities ahead of low business cost; in every other region of the country, business cost was more important than contact with universities. (As indicated earlier, the most important location factors are quality of life and access to skilled professionals. These factors have average scores well above those for business cost and university access.)

Approximately 32 percent of the MIT alumni entrepreneurs report having or anticipate having an ongoing connection with MIT. Most frequently, this ongoing connection has taken the form of recruiting new employees, doing joint research, and/or having faculty advisors or directors. The companies of those who graduated more than thirty years ago are slightly less likely to maintain regular contacts than are the most recent graduates.
Global pursuit of research- and technology-based industrial development has mushroomed in the past several decades. Greater Boston’s Route 128 and California’s Silicon Valley are the prototypes for other regions’ and other nations’ visions of their own futures. But what caused the original American Technopolis around Greater Boston to develop? What forces continue today to encourage young local scientists and engineers to follow entrepreneurial paths? This section of our report traces the evolution of MIT’s and Boston’s high-technology community, indicating the central role of MIT in building entrepreneurial practice and the supportive entrepreneurial environment or ecosystem. Our own takeoff from Webster defines an ecosystem as a complex community of living and nonliving things that are functioning together as a unit. We demonstrate here that such a system has been evolving for at least the 150 years since MIT’s founding to make entrepreneurship so vibrant in and around MIT.

Overwhelming anecdotal data argue that the general environment of the Greater Boston area beginning during the post-World War II period and, in particular, the atmosphere at MIT have played strong roles in affecting “would-be” local entrepreneurs. The legitimacy of “useful work” from MIT’s founding days was amplified and directed toward entrepreneurial expression by prominent early actions taken by administrative and academic leaders. Policies and examples that encouraged faculty and staff involvement with industry and, more important, their “moonlighting” participation in spinning off their ideas and developments into new companies were critical early foundation stones. MIT’s tacit approval of entrepreneurism, to some extent even making it the norm, was, in our judgment, a dramatic, perhaps the defining, contribution to the Greater Boston entrepreneurial culture. Key individual and institutional stimulants such as Stark Draper ‘26 and the MIT Enterprise Forum reinforced the potential entrepreneurial spinoffs that derived from a wide variety of advanced technology development projects in MIT labs as well as those of other local universities and medical centers, and in the region’s high-tech industrial firms. These actions fed into a gradually developing positive feedback loop of productive interactions with the investment community that, in time, created vigorous entrepreneurial activity especially at MIT, and a vital Route 128 community and beyond.

Early Influences: The Heritage of World War II Science and Technology

The atomic bomb, inertial guided missiles and submarines, computer-based defense of North America, the race to the moon, and the complex of high-technology companies lining the Route 128 highway outside of Boston are phenomena that became prominent in the post-World War II years. This was a time marked by a plethora of scientific and technological advances. The war had identified technology as the critical element upon which the survival of the nation rested and brought scientists from the shelter of their labs into the confidence of those in the highest levels of government. And in the postwar years, their power and their products and byproducts began to shape society, the economy, and the industrial landscape.

How had this started? The sudden need for war research in the early 1940s transformed universities like MIT into elite research and development centers where the best scientific and technological talent was mobilized for the development of specific practical devices for winning the war. Virtually whole universities redirected their efforts from pure scientific inquiry to the solving of critical problems. While many scientists
had to neglect their previous research in favor of war-related innovations, the scientists themselves were not neglected. Science and its offspring technology had become the property of the whole nation with an immediate relevance for all the people.

In addition to the urgent expansion and redirection of university research, the war made necessary the reorganization of research groups, the formation of new working coalitions among scientists and engineers, between these technologists and government officials, and between the universities and industry. These changes were especially noteworthy at MIT, which during the war had become the home of major technological efforts. For example, the MIT Radiation Laboratory, source of many of the major developments in wartime radar, evolved into the postwar MIT Research Laboratory for Electronics. The MIT Servomechanisms Lab, which contributed many advances in automatic control systems, started the research and development project that led to the Whirlwind Computer near the end of the war, created numerically controlled milling machines, and provided the intellectual base for undertaking the MIT Lincoln Laboratory in 1951. After the war, the Servo Lab became the Electronic Systems Lab and continues today as the MIT Laboratory for Information and Decision Systems. Lincoln Lab focused initially on creating a computer-based air defense system (SAGE) to cope with the perceived Soviet threat. To avoid continuing involvement in production and operations once the SAGE system was ready for implementation, MIT spun off a major group from Lincoln Lab to form the nonprofit MITRE Corporation, chartered to aid in the later stages of SAGE and to undertake systems analysis for the government. Lincoln then reaffirmed its R&D thrust on computers, communications, radar, and related technologies primarily for the U.S. Department of Defense. The MIT Instrumentation Lab, growing out of the wartime gun-sight work of Professor Charles Stark Draper, its founder and director throughout his career at MIT, continued its efforts on the R&D needed to create inertial guidance systems for aircraft, submarines, and missiles. It followed up with significant achievements in the race to the moon with developments of the guidance and stellar navigation systems for the Apollo program. The former Instrumentation Lab now bears Draper’s name in its spinoff-from-MIT nonprofit status.

Building on a Tradition
The World War II efforts and the immediate postwar involvements of MIT with major national problems built upon a much older tradition at MIT, enunciated by its founder William Barton Rogers in 1861 when he created an institution to “respect the dignity of useful work.” MIT’s slogan is “Mens et Manus,” Latin for “mind and hand,” and its logo shows the scholar and the craftsman in parallel positions. For a long time, MIT was seen as virtually alone as a university that embraced rather than shunned industry. Early alumni of “Boston Tech” (what MIT was “fondly” called before its move from Boston to Cambridge in 1910) pioneered new industries, such as automobiles. For example, Aurin Chase, MIT class of 1900, soon after in 1906 founded and ran Chase Motor Truck Company, a major truck and track vehicle supplier to the U.S. Army during World War I. From its start, MIT had developed close ties with technology-based industrialists, like Thomas Edison and Alexander Graham Bell, then later with its illustrious alumnus Alfred P. Sloan (MIT 1892) during his pioneering years at General Motors and with close ties to the growing U.S. petroleum industry. In the
1930s, MIT generated The Technology Plan to link industry with MIT in what became the first and is still the largest university-industry collaborative, the MIT Industrial Liaison Program.

These precedents were accelerated by the wartime leadership of MIT’s distinguished president, Karl Taylor Compton, who brought MIT into intimacy with the war effort while he headed all national R&D coordination in Washington. In the immediate postwar years, Compton pioneered efforts toward commercial use of military developments, among other things helping to create the first institutionalized venture capital fund, American Research and Development.

“AR&D was, in part, the brainchild of Compton, then head of MIT. In discussions with Merrill Griswold, chairman of Massachusetts Investors Trust, and Senator Ralph Flanders of Vermont, then president of the Federal Reserve Bank of Boston, Compton pointed out that some of the A-bomb technology that had been bottled up for four years had important industrial applications. At the same time, it was apparent to Griswold and Flanders that much of New England’s wealth was in the hands of insurance companies and trusts with no outlet to creative enterprises. Griswold and Flanders organized AR&D in June 1946 to supply new enterprise capital to New England entrepreneurs. [Compton became a board member, MIT became an initial investor, and a scientific advisory board was established that included three MIT department heads. General Georges] Doriot, who was professor of Industrial Management at Harvard, was later asked to become president” (Ziegler, 1982, p. 152). AR&D’s first several investments were in MIT developments, and some of the emerging companies were housed initially in MIT facilities. For example, in 1947, AR&D invested in High Voltage Engineering Corporation, which was located in the so-called “back lot” of MIT to take advantage of Professor John Trump’s Van de Graaf generator that stood there. AR&D also invested in Ionics Inc., which became the United States’ preeminent water purification company, purchased by General Electric in 2004 for $1.3 billion, but housed initially in the basement of the MIT Chemical Engineering building. MIT provided the space, heat, and light, and AR&D paid for the staff and out-of-pocket R&D expenses. That kind of arrangement certainly was most unusual for its time, albeit quite entrepreneurial, and today would be seen at most universities, including MIT, as a source of controversy and potential conflict. Compton’s successor as president of MIT, James Killian ’26, furthered the encouragement of entrepreneurial efforts by MIT faculty and staff as well as close ties with both industry and government. At various times Killian served on the boards of both General Motors and IBM and as President Eisenhower’s Science Advisor.

The traditions of MIT involvement with industry long since had been legitimatized in its official “Rules and Regulations of the Faculty,” encouraging active consulting by faculty members of about one day per week and, more impressive for its time, approving faculty part-time efforts in forming and building their own companies, a practice still questioned at many universities. Early faculty-founded companies include Arthur D. Little, Inc. (ADL), Edgerton Germeshausen and Grier (EG&G, Inc.), Bolt Beranek & Newman (BBN, Inc.), and many others. Initially, these were consulting firms that only later extended their domains into the realm of products. Faculty entrepreneurship, carried out over the years with continuing and occasionally heightened reservations about potential conflicts of interest, generally was extended to the research staff as well, who were thereby enabled to “moonlight” while being “full-time” employees of MIT labs and departments. The result is that a large fraction of all MIT spinoff enterprises, including essentially all faculty-initiated companies and many staff-founded firms, are started on a part-time basis, smoothing the way for many entrepreneurs to “test the waters” of high-tech entrepreneurship before making a full plunge. These companies are obvious candidates for most direct movement of laboratory technology into the broader markets not otherwise served by MIT. Few of the faculty founders, including Amar Bose ’51, founder of Bose Corporation, or Robert Langer ’74, a brilliant...
biomaterials scientist who has co-founded more than a dozen companies, ever resigned their MIT positions, preferring to remain at MIT for years while turning over the full-time reins to their former graduate students and lab colleagues. George Hatsopoulos ‘49, founder of ThermoElectron Corporation; Jay Barger ‘50, co-founder with another faculty colleague of Dynatech; Alan Michaels ‘44, founder of Amicon; and Tom Gerrity ‘63, co-founder of Index Systems, are among the few faculty who left to pursue their entrepreneurial endeavors full-time, with great success achieved in all four cases.

Although today regional and national governments worldwide seek to emulate the Boston-area pattern of technological entrepreneurship, in the early years the MIT traditions spread to other institutions very slowly. The principal early disciple was Frederick Terman ‘24, who took his Cambridge experiences as an MIT PhD student back to Stanford University, forsaking a faculty offer by MIT, to eventually lead Stanford into technological excellence. From his earlier MIT studies, amplified by his WWII service in Cambridge, Terman gained first-hand exposure to the close ties between MIT and industry, made more important to him by his being mentored by Professor Vannevar Bush ‘16, later dean of engineering and then vice president of MIT, who participated in founding the predecessor of Raytheon Corporation. The attitudes he developed while at MIT led Terman to encourage and guide his former students, such as William Hewlett ‘36, David Packard, and the Varian brothers, to start their high-technology firms and eventually to locate them next to the university in the newly formed Stanford Research Park. While these efforts obviously helped found what has become known as “Silicon Valley,” the resulting early proliferation of firms there came heavily from multiple spinoffs of other companies and did not follow the dominant Greater Boston pattern of direct fostering of new firms from MIT labs and departments. The MIT-Route 128 model still today remains unusual in its degree of regional entrepreneurial dependence upon one major academic institution.

The Neighboring Infrastructure

Yet, MIT has not been alone over the past several decades in nurturing the technology-based community of Boston, an entrepreneurial ecosystem now sprawling outward beyond Route 128 to the newer Route 495. Northeastern University, a large urban institution with heavy engineering enrollment and an active cooperative education program with industry, has educated many aspiring engineers who provide both support staff and entrepreneurs to the growing area. Wentworth Institute educates many of the technicians needed to support the development efforts at both the university labs as well as the spinoff companies. Boston University and Tufts University, both with strong science and engineering faculties, also play important roles. Even small liberal arts Brandeis University has participated, with Professor Orrie Friedman in 1961 starting Collaborative Research, Inc., forerunner of the much later biotechnology boom in the Greater Boston area. And that firm also illustrates the beginnings of cross-institutional ties among faculty entrepreneurs, with MIT Professor David Baltimore becoming the Chief Scientist of Collaborative while in his young thirties. Baltimore later became the founding director of the MIT Whitehead Institute, a major building block of the Cambridge biotech entrepreneurial cluster, and still later president of Rockefeller University, president of the California Institute of Technology, a Nobel Prize winner, and a co-founder of several companies.

Possibly surprising to readers from outside of the Boston area, Harvard University had not had a substantial role in entrepreneurial endeavors until the recent biotechnology revolution, in which Harvard Medical School and its affiliated teaching hospitals are playing a major role. In many ways over the years, Harvard has looked down its “classics” nose with disdain at the “crass commercialism” of its technological neighbor a few miles down the Charles River. An Wang, who worked at the Harvard Computation Laboratory before founding Wang Laboratories, Inc., is the most prominent exception to this rule. But change in regard to encouraging entrepreneurship has been in the wind over the past
two decades, even at Harvard. The outpouring of excellent research and discovery from Harvard’s Chemistry and Biology Departments, as well as from the Harvard Medical School across the river in Boston, have caused Harvard faculty and staff recently to become much more active and successful participants in entrepreneurial startups, although not without voiced reluctance and controversy at the university. In fact, in a dramatic early attempted revolution of its policies, Harvard asked Professor of Biochemistry Mark Ptashne to start Genetics Institute in 1979, a company in which Harvard would hold 15 percent to 20 percent equity (something MIT has never done!). But protest by critics as to possible influence of such ownership caused Harvard to pull out. Ptashne went ahead and formed the company, while still remaining on the Harvard University faculty. In 1989, the Harvard Medical School took the far-reaching step of organizing a venture capital fund (discontinued a few years later) to invest in new companies whose founders relate to Harvard Medical, in some ways mimicking MIT’s much earlier but less-direct activities in regard to AR&D, but nevertheless a pioneering step among academic institutions. And, recently, a group of Harvard Medical-affiliated hospitals (Partners Healthcare) has formed its own venture capital firm to invest in its potential commercial spinoffs.

Encouraged no doubt by the unique venture capitalist role of Professor Doriot, and separated by the Charles River from main campus influence, many Harvard Business School graduates joined alumni from the MIT undergraduate management program and, after its 1951 founding, from the MIT Sloan graduate school as well, in finding welcome homes in even the early high-tech company developments. These business school graduates got involved in startup teams initially as administrators and sales people, and in more recent years participating frequently as primary founders. Thus, Aaron Kleiner ’69 from the MIT Sloan School of Management shares the founding of nine high-technology companies with his MIT computer science undergraduate roommate Raymond Kurzweil ’70. And Robert Metcalfe ’68 combined MIT educational programs in both engineering and management prior to his launch of 3Com. The Greater Boston environment has become so tuned to entrepreneurship that even student projects with local companies, a part of routine course work in every local management school, have ended up helping to create numerous entrepreneurial launches. Several firms were generated from feasibility studies done as part of Doriot’s famed “Manufacturing” course at the Harvard Business School. And Inc. magazine founder Bernard Goldhirsh ’61 credited an MIT Sloan School marketing course with confirming for him the huge market potential for a magazine targeted toward entrepreneurs and small business managers.

Boston entrepreneurs also eventually benefited from understanding bankers and private investors, each group setting examples to be emulated later in other parts of the country. The First National Bank of Boston (later becoming BankBoston and now part of Bank of America) had begun in the 1950s to lend money to early-stage firms based on receivables from government R&D contracts, a move seen at the time as extremely risky even though the loans seemed to be entirely secured. Arthur Snyder, then vice president of commercial lending of the New England Merchants Bank (which became Bank of New England and later part of Citizens Bank), regularly took out full-page ads in the Boston Globe that showed himself with an aircraft or missile model in his hands, calling upon high-technology entrepreneurs to see him about their financial needs. Snyder even set up a venture capital unit at the bank (one of the first in the United States) to make small equity investments in high-tech companies to which he had loaned money. Several scions of old Boston Brahmin families became personally involved in venture investments even in the earliest time period. For example, in 1946, William Coolidge helped arrange the financing for Tracerlab, MIT’s first nuclear-oriented spinoff company, eventually introducing William Barbour ’33 of Tracerlab to AR&D, which carried out the needed investment (Ziegler, 1982, p. 151). Coolidge also invested in National Research Corporation (NRC), a company founded by MIT.

32
alumnus Richard Morse ’33 (later the first teacher of entrepreneurship at MIT) to exploit advances in low-temperature physics. NRC later created several companies from its labs, retaining partial ownership in each as they spun off, the most important being Minute Maid orange juice, later sold to Coca-Cola. NRC’s former headquarters building, constructed adjacent to MIT on Memorial Drive in Cambridge, now houses the classrooms of the MIT Sloan School of Management. Incidentally, long before the construction of Route 128, Memorial Drive used to be called “Multi-Million Dollar Research Row” because of the several early high-technology firms next to MIT, including NRC, Arthur D. Little Inc., and Electronics Corporation of America. The comfortable and growing ties between Boston’s worlds of academia and finance helped create bridges to the large Eastern family fortunes—the Rockefellers, Whittneys, and Mellons, among others—who also invested in early Boston startups. Although these funds existed, they were not available in generous amounts. Even in 1958, Ken Olsen ’50 and Harlan Anderson ’53 had to surrender more than 70 percent of startup Digital Equipment Corporation (DEC) for the $70,000 they received from AR&D. Other aspects of the surrounding infrastructure also were slow in happening. By and large, lawyers were uninformed about high-tech deals, and general law firms had no specialists in intellectual property. As late as the early 1980s, the MIT and Harvard co-founders of Zero Stage Capital, Boston’s first “seed capital” fund, eventually found Paul Brontas, the senior partner of Boston’s then-leading law firm Hale & Dorr, to be among the only lawyers in town who knew how to set up the complex structure of a venture capital firm.

By the end of the 1940s, when space constraints in the inner cities of Boston and Cambridge might have begun to be burdensome for continuing growth of an emerging high-technology industrial base, the state highway department launched the building of Route 128, a circumferential highway (Europeans and Asians would call it a “ring road”) around Boston through pig farms and small communities. Route 128 made suburban living more readily accessible and land available in large quantities and at low prices. MIT Lincoln Lab’s establishment in 1951 in Concord, previously known only as the site of the initial 1776 Lexington-Concord Revolutionary War battle with the British, “the shot heard round the world,” or, to some, as the home of Thoreau’s Walden Pond, helped bring advanced technology to the suburbs. Today Route 128, proudly labeled by Massachusetts as “America’s Technology Highway,” reflects the cumulative evidence of sixty years of industrial growth of electronics, computer, and software companies. Development planners in some foreign countries occasionally have been confused by consultants and/or state officials into believing that the once-convenient, now traffic-clogged Route 128 highway system actually caused the technological growth of the Greater Boston area. At best the Route 128 highway itself, later followed by the more distant Route 495 circumferential road, has been a moderate facilitator of the development of this high-technology region. More likely the so-called “Route 128 phenomenon” is a result and a beneficiary of the growth caused by the other influences identified earlier.

Throughout this period since World War II (and to a lesser extent prior to that time), the sometimes-overlooked but in reality quite vital formation of high-tech companies in the Greater Boston area, as well as in most other high-tech regions in the United States, has been aided powerfully, even if indirectly, by government research funding. One visible example at MIT and nearby was the foundation for the modern computer industry, which benefited from hundreds of millions of dollars of defense research into semiconductors and electronics, much of it spent in New England.

MIT depends on federal agencies for approximately 75 percent of its $587.5 million of on-campus-sponsored research. Another $636 million of research and development is at MIT Lincoln Laboratories, which MIT runs for the Air Force. (Ken Olsen, founder of Digital Equipment Corporation, worked on computer research and development there.) A very early (1964) study by Roberts documented forty-seven companies that
already had emerged from Lincoln Lab. On the occasion of its fiftieth anniversary in 2001, Lincoln Lab itself documented eighty-two companies that had been founded by former employees, many of whom were not MIT alumni.

On-campus research accounts for about 29 percent of the Institute’s budget and, because of these research funds, the faculty is likely to be much larger than otherwise would be the case. In addition, more than $52 million goes to hiring graduate students as research assistants. The flow of federal dollars thus helps to bring thousands of the brightest young students in the United States and from other countries to Boston, involves them in cutting-edge research projects, and helps pay for their graduate education. As we’ve seen, many of these students stay in the area and start companies, often with their faculty mentors.

Accelerating Upward from the Base: Positive Feedback

A critical influence on entrepreneurship in Greater Boston (and we assert in other regions as well, when they do indeed take off) is the effect of “positive feedback” arising from the early role models and successes. Entrepreneurship, especially when successful, begets more entrepreneurship. Schumpeter observed: “The greater the number of people who have already successfully founded new businesses, the less difficult it becomes to act as an entrepreneur. It is a matter of experience that successes in this sphere, as in all others, draw an ever-increasing number of people in their wake” (1936, p. 198). This certainly has been true at MIT.

The earliest faculty founders were senior faculty of high academic repute at the times they started their firms. Their initiatives as entrepreneurs were evidences for others at MIT and nearby that technical entrepreneurship was a legitimate activity to be undertaken by strong technologists and leaders. Karl Compton’s unique role in co-founding AR&D while president of MIT furthered this image, as did the MIT faculty’s efforts in bringing early-stage developments to AR&D’s attention. Obviously, “if they can do it, then so can I!” might well have been a rallying cry for junior faculty and staff, as well as for engineers in local large firms. Our comparative study years ago of Swedish and Massachusetts technological entrepreneurs found that, on average, the U.S. entrepreneurs could name about ten other new companies before they started their own, three or four of which were in the same general area of high-technology business. Few of the Swedish entrepreneurs could name even one or two others like them. A prospective entrepreneur gains comfort from having visibility of others like herself or himself; this evidence is more likely if local entrepreneurship has a critical mass, making the individual’s break from conventional employment less threatening.

The positive feedback loop affecting MIT’s entrepreneurial output is no doubt most affected by the increasing attraction of the Institute to students, staff, and faculty who are entrepreneurially inclined even before they arrive. The more entrepreneurial MIT appears to be, the more potential entrepreneurs want to be there. Table 8 indicates the responses from those MIT alumni entrepreneurs who completed the 2003 survey. Clearly, for more than fifty years, MIT has been attractive to those who later

<table>
<thead>
<tr>
<th>Graduation Decade</th>
<th>1950s (N=207)</th>
<th>1960s (N=313)</th>
<th>1970s (N=373)</th>
<th>1980s (N=315)</th>
<th>1990s (N=214)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chose MIT for its Entrepreneurial Reputation</td>
<td>17%</td>
<td>12%</td>
<td>19%</td>
<td>26%</td>
<td>42%</td>
</tr>
</tbody>
</table>
form new companies. But the table shows an amazing escalation over the past thirty years. Indeed, 42 percent of those 1990s graduates who already have formed companies within their very first decade out of MIT claim they were attracted to MIT originally by its reputed entrepreneurial environment. The more entrepreneurs MIT produces, the stronger the entrepreneurial environment and reputation, the more likely entrepreneurs, both students and faculty, are attracted to come to MIT!

The growing early entrepreneurial developments at MIT and, more broadly, in the Greater Boston area also encouraged their brave investors and brought other wealthy individuals forward to participate. As an example of the spiraling growth of new firms, even in the early days, Ziegler (1982) shows the proliferation of thirteen nuclear-related companies ‘fissioning’ within fifteen years from Tracerlab’s 1946 founding, including Industrial Nucleonics (which became Accuray), Tech Ops, and New England Nuclear (purchased by DuPont). Inevitably, that led not only to more new firms but to a technological cluster of companies that interacted with each other to the benefit of all. With now more than fifty years of intensive regional entrepreneurial activity in the Boston area, a positive feedback loop of new company formation has generated significant outcomes, even if the initial rate of growth was slow. In the mid-1960s, through dramatic proliferation of spinoff companies, Fairchild Semiconductor (co-founded by MIT alumnus Robert Noyce ‘53 before he left to co-found Intel) gave birth to similar and rapid positive feedback that launched the semiconductor industry in Silicon Valley. And Tracor, Inc., provided a comparable impetus to new-company formation, especially in military electronics, in Austin, Tex.

A side benefit of this growth, also feeding back to help it along, is the development of supporting infrastructure in the region—technical, legal, accounting, banking, and real estate, all better understanding how to serve the needs of young technological firms. In Nancy Dorfman’s early (1983) assessment of the economic impact of the Boston-area developments, she observes “a network of job shoppers that supply made-to-order circuit boards, precision machinery, metal parts, and sub-assemblies, as well as electronic components, all particularly critical to new startups that are developing prototypes and to manufacturers of customized equipment for small markets. In addition, dozens if not hundreds of consulting firms, specializing in hardware and software, populate the region to serve new firms and old.” Of course, this massive network is itself made up of many of the entrepreneurial firms we have been investigating. Within this infrastructure in the Boston area are now “not-so-new” “networking” organizations, like the MIT Enterprise Forum (to be discussed later) and the 128 Venture Group, which bring together on a monthly or even more frequent basis entrepreneurs, investors, and other participants in the entrepreneurial community, contributing further positive loop gain.

**Technology Clusters**

This positive feedback effect certainly occurred in the Greater Boston region as a whole and, as illustrated by the Tracerlab and Fairchild examples, also frequently occurs in many places at the single organizational level. As one individual or group departs a given lab or company to form a new enterprise, the entrepreneurial phenomenon may mushroom and tend to perpetuate itself among others who learn about the spinoff and also get the idea of leaving. Sometimes one group of potential entrepreneurs feels it is better suited than its predecessors to exploit a particular idea or technology, stimulating the second group to follow quickly. Five groups left the Draper Lab over a two-year period to establish new companies based on the lab’s advances in micro-electronics. The “outside environment” can help this process by becoming more conducive to additional new enterprise formation. In particular, venture capitalists, learning more about a “source organization” of new ideas and/or key people from the organization’s earlier spinoffs, may actively seek to encourage further spinoffs from the same source. This certainly played an important role in the 1980s’ beginning of the still-
The continuing proliferation of biotechnology spinoffs from MIT and Harvard academic departments and medical centers. Sometimes a “keystone” company assists many others to be formed, as was done by BioInformation Associates, a company formed by eight MIT professors, including Anthony Sinskey '67 and Charles Cooney '70, to provide technical and strategic assistance to others interested in starting new firms. It provided major help in the creation and development of Genzyme Corporation, among others. And the increasing critical mass of companies and their skilled scientists and engineers attract other companies, even very large global firms like Novartis, to locate laboratories and other facilities in the midst of the clusters, enhancing the availability of scientists and engineers, and further strengthening the relevant infrastructure.

As evidence of the results that come from this positive feedback effect within a given industry, we show two local maps of the area near MIT. The first, Figure 15, indicates the recent status of the biotechnology cluster in and around Kendall Square, Cambridge, within blocks of MIT. Ninety-five biotech companies, even very large global firms like Novartis, to locate laboratories and other facilities in the midst of the clusters, enhancing the availability of scientists and engineers, and further strengthening the relevant infrastructure.

Figure 15
Biotech Companies Clustered in Greater Kendall Square, Cambridge, Mass.
companies had been documented by early 2008 as located within this complex, compared with fifty-five just three years prior. Thirteen of the Kendall Square life sciences companies accounted for two-thirds of the $1.8 billion Massachusetts companies spent on R&D in 2000. By the year 2001, twenty-one of the Kendall Square companies either were founded by MIT alumni or faculty, or had MIT-licensed technology; their revenues were $2.5 billion.

Since 2001, the biotech numbers have continued to grow substantially. In ongoing research on the MIT-related life sciences complex in Cambridge, Professor Fiona Murray of MIT Sloan now finds that sixty-six of the 493 MIT “life scientists” (including those at the affiliated Broad and Whitehead Institutes) have founded or served on the boards of directors of at least one venture-funded company, totaling 134 companies in all. Eighteen of these faculty or staff have founded or been board members of at least three companies each, with one MIT faculty member having twenty such relationships. Fifty additional MIT “life science” people serve as science advisory board members of an additional 108 companies, bringing a total of at least 242 life-science companies into strong ties with the MIT community. These ties are both cause and result of the interconnections between MIT and the entrepreneurial and industrial community. A large fraction of these life sciences faculty, post-docs, and staff do not have MIT degrees, and therefore are not counted among the MIT alumni entrepreneurship firms discussed in the earlier part of this report. Therefore, the economic and technological impact of these companies, by and large, supplement the data presented in the beginning of this report.

Another sign of linkage of this cluster to MIT is the record of biotech/biomedical winners and runners-up in the MIT $50K Competition, the student-run business plan competition that will be discussed in greater depth later in this report. Data compiled by the MIT Entrepreneurship Center, listed in Table 9, shows fourteen bio-related companies in the last decade, several of which became real companies following their MIT $50K successes.

<table>
<thead>
<tr>
<th>Company</th>
<th>Year</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>SteriCoat</td>
<td>2006</td>
<td>Winner</td>
</tr>
<tr>
<td>Balico</td>
<td>2005</td>
<td>Winner</td>
</tr>
<tr>
<td>Active Joint Brace</td>
<td>2004</td>
<td>Winner</td>
</tr>
<tr>
<td>SmartCells</td>
<td>2003</td>
<td>Winner</td>
</tr>
<tr>
<td>Ancora Pharmaceuticals</td>
<td>2002</td>
<td>Finalist</td>
</tr>
<tr>
<td>Crosslink Medical</td>
<td>2002</td>
<td>Finalist</td>
</tr>
<tr>
<td>Angstrom Medical</td>
<td>2001</td>
<td>Winner</td>
</tr>
<tr>
<td>Iptyx</td>
<td>2001</td>
<td>Finalist</td>
</tr>
<tr>
<td>SiteSpecific Pharma</td>
<td>2001</td>
<td>Finalist</td>
</tr>
<tr>
<td>SmartCure</td>
<td>2001</td>
<td>Finalist</td>
</tr>
<tr>
<td>EyeGen</td>
<td>2000</td>
<td>Winner</td>
</tr>
<tr>
<td>MolecularWare</td>
<td>1999</td>
<td>Winner</td>
</tr>
<tr>
<td>Virtmed</td>
<td>1998</td>
<td>Finalist</td>
</tr>
<tr>
<td>Actuality Systems</td>
<td>1997</td>
<td>Winner</td>
</tr>
</tbody>
</table>

A second cluster has formed rapidly in the energy field. Over the past five decades, 3 percent of MIT entrepreneurs classified their firms as being in the energy sector. We now estimate that MIT alumni are creating thirty to thirty-five new energy-focused firms every year. Several hundred companies are in the New England energy cluster, with 263 in Massachusetts alone by early 2008. In Figure 16, we show the Boston metropolitan portion, containing twenty-two energy companies in Cambridge and twenty-five more in Boston. The broad geographic distribution of the energy firms, relative to the biotech companies shown in Figure 15, reflect the large number of source organizations of the energy companies, their wide diversity of technological bases, and their need for somewhat greater physical space than is readily available in central Cambridge. A high percentage of the new energy firms are MIT-related in terms of their founders and/or technology sources.
Other “Pulls” on Potential Entrepreneurs

In addition to the general environmental encouragements on technological entrepreneurship in MIT’s surroundings, specific “pulls” are at work on some of the people, making entrepreneurship an attractive goal to attain. Such influences may inhere in the general atmosphere of a particular organization, making it more conducive to the new enterprise spinoff process. For example, until his recent death, Stark Draper ’26, visionary leader of the MIT Instrumentation Laboratory (later renamed the Draper Lab), was a key source of encouragement to anyone who came in contact with him. No wonder that the National Academy of Engineering established the Draper Prize to be the equivalent in engineering of the Nobel Prizes in science. Having had the good fortune to fly coast-to-coast with Draper one night on a “red eye” from Los Angeles, one of our co-authors learned much about Draper’s unique attitudes toward developing young technologists.

“I try to assign project managers who are just a bit shy of being ready for the job,” Draper said. “That keeps them really hopping when the work gets underway, although the government officials usually want to wring my neck.”

“I break up successful teams once they’ve received their honors. That way every one remembers them for their success, rather than for some later failure. Also, this causes every young person in the Lab to be sitting within one hundred feet of someone who’s had his hand shaken by the President of the United States.
“The Lab is a place for young people to learn. Then they can go someplace else to succeed.

“When I give speeches, I single out those who have already left the Lab—to become professors elsewhere, VPs of Engineering in industry, or founders of their own companies. Staying behind in the lab is just for a few old ‘beezers’ like me who have no place else to go!”

Draper’s organizational environment was one of high achievement, but with negative incentives for remaining too long. Salaries flattened out quickly, causing the income gap between staying and leaving to grow rapidly as an engineer gained experience. Engineers completing a project had a sharp breakpoint, a good time for someone confident from the success of his or her project to spin off. In retrospect, Stark Draper clearly consciously tried to encourage spinoffs of all sorts from his laboratory, perhaps the highest attainment achievable by an academic scientist.

No questions were asked if Instrumentation Lab employees wanted to borrow equipment to take home over the weekend, and many of them began their new companies “moonlighting” with this kind of undisguised blessing. Draper wanted reasonably high levels of turnover and constant introduction to the Lab of bright, eager, young people. Over a fifteen-year period, during which we traced Lab performance, the average age of Instrumentation Laboratory employees remained at thirty-three years, plus or minus six months. This young-age stability, maintaining the lab’s vitality and fighting off technological obsolescence, was not true at most of the other MIT labs we studied.

Draper apparently produced similar effects in his teaching activities at MIT. Tom Gerrity ’63, founder of Index Systems, which, in turn, later created Index Technology and Applied Expert Systems as sponsored spinouts, reports that Draper’s undergraduate elective subject showed him the importance of being able to put together lots of different skills and disciplines to produce a result. Gerrity adopted this systems point of view in co-founding Index several years later, after three MIT degrees and a stint as a faculty member in the MIT Sloan School of Management. Still later, Gerrity became dean of the Wharton School of the University of Pennsylvania.

Some other MIT laboratory directors followed similar patterns of entrepreneurial “sponsorship” in smaller, less-well-known labs. For example, the head of the Aero-elastic and Structures Laboratory of the MIT Department of Aeronautics and Astronautics had the attitude that the lab provided an internship type of position and that staff members were more or less expected to move on after a reasonable period. In other labs, the environment just seemed to breed entrepreneurship. Douglas Ross ’54, who left the Electronics Systems Lab with Jorge Rodriguez ’60 to found SofTech, Inc., commented: “The entrepreneurial culture is absolutely central to MIT. The same mix of interests, drives, and activities that makes a [Route] 128-type environment is the very life blood of MIT itself. No other place has the same flavor.” Ross epitomizes this “life blood” quality. When SofTech was established, MIT took the exceptional step for that time of making a small direct equity investment in his ground-zero company, joining a large number of friends and associates who shared great confidence in Ross’s vision.

Indeed, the challenging projects underway at most of the labs create a psychological “let-down” for their participants when the projects end. Many of the entrepreneurs indicate that they became so involved with their work on a given project that, when these projects were completed, they felt that their work, too, was completed. Several of the entrepreneurs attest that their sense of identification with their lab began to wane as the project neared completion. Only through the challenge of starting their own enterprises did they think they could recapture the feelings that they were doing something important.

Beyond the labs themselves, other activities at MIT have over the years encouraged entrepreneurship. The MIT Alumni Association undertook special efforts to encourage
entrepreneurial impact among its members, which will be discussed in depth later. All of these efforts have spread the word, legitimized the activities of entrepreneurship, and produced significant results.

New policies instituted by John Preston and strengthened by Lita Nelsen ’64, successive directors of MIT’s Technology Licensing Office (to be discussed in more detail), further encouraged entrepreneurship, especially by faculty and research staff. In addition to conventional technology licensing to mainly large corporations for fees, the TLO actively licenses MIT-originated technology in exchange for founder stock in a new enterprise based on that technology. In the first year of this new practice, 1988, six new companies were born based on licensed MIT technology, with sixteen firms started in the second year of policy implementation. Complete, more recent TLO spinoff data are shown later.

A Unique Culture

History, tradition, and accelerating forces contribute over time to creating a culture. Our studies of MIT alumni entrepreneurs also draw on a series of telephone interviews with MIT founders. We asked these founders whether and how their stay at MIT had played a role in their decision to start their own companies and, if it had, how it had done so. All agreed that MIT had encouraged them to become risk-takers. One founder sees it this way: “Let me try to give you my personal perspective about ‘risk-taking.’ I think it is a combination of several different factors. I knew I was not going to work for big companies when I was about to leave MIT. I would rather take the risk of failure than the risk of becoming nobody. There must be many alumni who felt the same way I did. MIT offers great mentors [professors] and more opportunities [professors’ consulting/research activities] for students to test the water in establishing their own businesses. MIT exposes students to cutting-edge technologies and new ideas. It probably is easier to explore business potential of these new ideas and technologies as entrepreneurs. It seems to be quite natural that MIT becomes a cradle of entrepreneurs.”

Respondents indicated that being an MIT student not only encourages individuals to become entrepreneurs, but also facilitates social interaction, enhances their reputations [association with MIT], and trains them to solve problems—all of which are valuable inputs to new-venture development. One surveyed alumnus stated: “I look at the MIT experience as training in problem solving. Business is a series of ‘problem sets’ that must be solved, so MIT is a key training ground.”

Another founder says that MIT instills the entrepreneurial spirit in its graduates. “You know that lots of people [students and professors] start their own companies.” Many of this former student’s classmates started businesses while in school. This founder combined an electrical engineering degree with a management degree from the MIT Sloan School, where he learned that high risk could lead to high return. After graduation, he passed up a safer job with a large company to take a senior position in a startup.

Until his recent death, Teradyne co-founder/CEO Alex d’Arbeloff taught a graduate class at MIT Sloan. Having the entrepreneur who founded and built a billion-dollar high-tech company as a course instructor must have been a powerful role model for his students. Amar Bose, founder/CEO of Bose Corporation, still teaches acoustics classes at MIT. Several founders observed that enrollment at MIT was the first time they realized they were not the “smartest person in the world.” One founder felt that this teaches humility, critical to CEOs who must learn to listen to customers and to respect the opinions of their employees. On the other hand, successful completion of an MIT education instills the confidence that bright people working together can solve problems.

“It’s a ‘hands-on’ place; if there’s a problem, students are encouraged to go down to the basement, build the appropriate equipment and develop a solution,” said Ray Stata ’57, co-founder and long-time CEO of Analog Devices (fiscal 2008 revenues of $2.6 billion). He asserted that MIT taught him that no
problem was too difficult to solve. It was just a question of how hard and how long you were willing to work.

Along the same lines, another founder said that, because of the research and industrial ties of the faculty, MIT students get to work on “real stuff.” Students are “right in the middle of something big”—topics being argued about and worked on at that moment in the industrial world. Professors don’t hesitate to work on real-world industrial and global problems. Founders point out that anyone who’s at MIT for a few years knows the state of the art in his or her field. Other founders mentioned the importance of ties forged at MIT with fellow students who later become customers or co-founders: “The ‘brass rat’ [MIT’s unique and long-time traditional graduation ring that features a beaver] opens lots of doors.”

“Pushes” on Entrepreneurship

Some environmental forces affecting the “would-be” entrepreneur are the “negatives” about his or her present employer, rather than the “positives” of going into business. The uncertainties due to the ups and downs of major projects often have been cited as a source of grief, and sometimes even have led to expulsion of individuals into a reluctant entrepreneurial path. The evidence suggests that a stable work environment probably would produce far fewer entrepreneurial spinoffs than one marked by some instability. For example, the entrepreneurs who emerged from one large diversified technological firm most frequently rank “changes in work assignment” as the circumstance that precipitated formation of their companies, followed by “frustration in job.” One-fourth of the companies from that firm were founded during the three years that the firm suffered some contract overruns and laid off some technical people, although none of those actually laid off from this firm became entrepreneurs. The “worry about layoff” and seeing the parent firm in a terrible state are cited by many of that period’s spinoffs. Even at the Draper Lab, staff was cut by about 15 percent through layoff and attrition after the completion of the Apollo lunar program, stimulating a number of new firms. Ninety-two percent of the spinoffs from the MIT Electronic Systems Lab (ESL) occurred during an eight-year period, when only 28 percent would have been expected if spinoffs occurred randomly over time as a function only of total employment. The large number of ESL projects completed during that period is one explanation for the “lumpiness” of new company creation.

Frustration with the noncommercial environment in the MIT labs and academic departments bothered some of the potential entrepreneurs. Margaret Hamilton, founder of Higher Order Software, exclaims: “The Draper nonprofit charter was frustrating, especially if you wanted to get into something exciting. There was always the sense of living in a no-man’s land.” Many of the entrepreneurs wanted to market specific devices or techniques. Others had no definite products in mind but saw clear prospects for further applications of the technology or skills they had learned at their current organizations. The prospective entrepreneurs usually felt they could not exploit these possibilities at MIT labs, because the labs concentrated on developing new technology rather than finding applications for existing technology. Unfortunately for their industrial employers, many of the spinoffs from industrial companies report the same frustration, despite the not unreasonable presumption that their large-firm employers should welcome at least some of these new ideas. In Silicon Valley, too, Cooper (1986) found that 56 percent of the new company founders had been frustrated in their previous jobs. Yet frustration should manifest itself more reasonably with just job-changing, not company-creating, behavior. Clearly, the overall environment promoting entrepreneurship in Greater Boston, and in Silicon Valley as well, makes the new-company option an active choice if other conditions are right.

As evidence of the significant historic flow of MIT alumni-founded firms, we show in Table 10 a small selection of prominent firms founded by MIT graduates. (Many other companies in a wide diversity of fields could be added to this list, such as Campbell
Table 10
Examples of Important MIT Alumni-Founded Companies (ordered by $ sales)*

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Employment (thousands)</th>
<th>Sales* (millions)</th>
<th>MIT Founder</th>
<th>MIT Class</th>
<th>Year Founded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Corporation</td>
<td>Santa Clara, Calif.</td>
<td>86</td>
<td>38,300</td>
<td>Robert Noyce</td>
<td>1954, 1968</td>
<td></td>
</tr>
<tr>
<td>Hewlett-Packard</td>
<td>Palo Alto, Calif.</td>
<td>156</td>
<td>22,600</td>
<td>William Hewlett</td>
<td>1936, 1939</td>
<td></td>
</tr>
<tr>
<td>Raytheon Co.</td>
<td>Lexington, Mass.</td>
<td>72</td>
<td>21,300</td>
<td>Vannevar Bush</td>
<td>1916, 1922</td>
<td></td>
</tr>
<tr>
<td>McDonnell Douglas</td>
<td>St. Louis, Mo.</td>
<td>70</td>
<td>14,470</td>
<td>James McDonnell, Jr.</td>
<td>1925, 1939</td>
<td></td>
</tr>
<tr>
<td>Texas Instruments</td>
<td>Dallas, Tex.</td>
<td>30</td>
<td>13,830</td>
<td>Cecil Green</td>
<td>1923, 1930</td>
<td></td>
</tr>
<tr>
<td>Qualcomm Inc.</td>
<td>San Diego, Calif.</td>
<td>13</td>
<td>9,800</td>
<td>Irwin Jacobs</td>
<td>1959, 1985</td>
<td></td>
</tr>
<tr>
<td>ThermoElectron</td>
<td>Waltham, Mass.</td>
<td>30</td>
<td>9,000</td>
<td>George Hatsopoulos</td>
<td>1949, 1956</td>
<td></td>
</tr>
<tr>
<td>America Online</td>
<td>Dulles, Va.</td>
<td>15</td>
<td>6,110</td>
<td>Marc Seriff</td>
<td>1973, 2001</td>
<td></td>
</tr>
<tr>
<td>Symantec Corp.</td>
<td>Cupertino, Calif.</td>
<td>16</td>
<td>4,143</td>
<td>Denis Coleman</td>
<td>1968, 1982</td>
<td></td>
</tr>
<tr>
<td>Analog Devices</td>
<td>Norwood, Mass.</td>
<td>9</td>
<td>2,570</td>
<td>Ray Stata, Matthew Lorber</td>
<td>1957, 1965</td>
<td></td>
</tr>
<tr>
<td>Gillette</td>
<td>Boston, Mass.</td>
<td>29</td>
<td>2,250 (in 2003)</td>
<td>William Emery Nickerson</td>
<td>1876, 1901</td>
<td></td>
</tr>
<tr>
<td>Bose Corp.</td>
<td>Framingham, Mass.</td>
<td>10</td>
<td>2,000</td>
<td>Amar Bose</td>
<td>1956, 1964</td>
<td></td>
</tr>
<tr>
<td>Teradyne</td>
<td>Boston, Mass.</td>
<td>4</td>
<td>1,600</td>
<td>Alex d’Arbeloff, Nick DeWolf</td>
<td>1949, 1960</td>
<td></td>
</tr>
<tr>
<td>International Data Group (IDG)</td>
<td>Boston, Mass.</td>
<td>13</td>
<td>1,520</td>
<td>Patrick McGovern</td>
<td>1959, 1964</td>
<td></td>
</tr>
<tr>
<td>3Com Corporation</td>
<td>Marlborough, Mass.</td>
<td>6</td>
<td>1,300</td>
<td>Robert Metcalfe</td>
<td>1969, 1979</td>
<td></td>
</tr>
<tr>
<td>Sepracor</td>
<td>Marlborough, Mass.</td>
<td>2</td>
<td>1,225</td>
<td>Robert Bratzler</td>
<td>1975, 1984</td>
<td></td>
</tr>
<tr>
<td>Millennium Pharmaceuticals</td>
<td>Cambridge, Mass.</td>
<td>1</td>
<td>527</td>
<td>Eric Lander</td>
<td>1986, 1993</td>
<td></td>
</tr>
</tbody>
</table>

*All sales and employment data are from 2006 or the most recent year available, and are rounded off to the nearest whole number.
As we have pointed out before, because of founder deaths or company mergers, most of the firms shown here are conservatively omitted from the economic impact projections in our study.) In Table 11, we show a similar small selected list of more recently created, growing MIT alumni companies, which also may spawn giants in future years. (Due to the young age and small size of this group, we are aware disproportionately about firms near MIT. Over time, we assume that most alumni-founded companies will be located outside of Massachusetts, as we demonstrated earlier in this report.) The combination of large and small, old and young, mature and rapidly growing, always has characterized the mix of MIT alumni-founded enterprises.

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Employment</th>
<th>Sales* (millions)</th>
<th>MIT Founder</th>
<th>MIT Class</th>
<th>Year Founded</th>
</tr>
</thead>
<tbody>
<tr>
<td>A123 Systems</td>
<td>Watertown, Mass.</td>
<td>1,800</td>
<td>41</td>
<td>Ric Fulp, Yet-Ming Chiang</td>
<td>2006</td>
<td>2001</td>
</tr>
<tr>
<td>Lilliputian Systems</td>
<td>Wilmington, Mass.</td>
<td>54</td>
<td>3</td>
<td>Samuel Schaevit, Aleks Franz</td>
<td>2000</td>
<td>2001</td>
</tr>
<tr>
<td>LS9, Inc.</td>
<td>San Francisco, Calif.</td>
<td>33</td>
<td>----</td>
<td>Noubar Afeyan, David Berry</td>
<td>1987</td>
<td>2000</td>
</tr>
<tr>
<td>Rive Technology</td>
<td>Ochelata, Okla.</td>
<td>2</td>
<td>----</td>
<td>Javier Garcia Martinez</td>
<td>2004</td>
<td>2006</td>
</tr>
<tr>
<td>Svaya Nanotechnologies</td>
<td>Los Angeles, Calif.</td>
<td>5</td>
<td>----</td>
<td>Benjamin Wang, Erik Allen, Kevin Krogman</td>
<td>2007</td>
<td>2008</td>
</tr>
<tr>
<td>Visible Measures</td>
<td>Cambridge, Mass.</td>
<td>40</td>
<td>----</td>
<td>Brian Shin</td>
<td>2006</td>
<td>2005</td>
</tr>
<tr>
<td>Zipcar</td>
<td>Cambridge, Mass.</td>
<td>16</td>
<td>3</td>
<td>Robin Chase</td>
<td>1986</td>
<td>2000</td>
</tr>
</tbody>
</table>

*All sales and employment data are from 2006 or the most recent year available, and are rounded off to the nearest whole number.
An Evolving MIT Internal Entrepreneurial Ecosystem

As indicated above, the history and unique culture of MIT began even before its founding in 1861 with the stated vision of William Barton Rogers for creating an institution dedicated to useful knowledge. But institutional elements in support of this culture, both within and surrounding MIT, were slow in coming until about thirty-five years ago. In 1964, when Edward Roberts started his first research project to study entrepreneurial spinoff companies from MIT labs and departments, he was able to find many companies previously formed, some of which already were quite successful (Roberts, 1991). But only one subject in entrepreneurship was being taught at MIT (begun in 1961, 100 years after MIT’s birth) and no student clubs existed to encourage potential or would-be entrepreneurs.

Alumni Initiatives: Seminars and the MIT Enterprise Forum

In 1969, a small volunteer group of the MIT Alumni Association organized the MIT Alumni Entrepreneurship Seminar Program, hoping to attract at least thirty New England alumni from the classes of 1953-1963 to a day-and-a-half weekend session at MIT on “Starting and Building Your Own Company.” All sessions on topics such as organizing, financing, marketing, and legal issues were to be run by Greater Boston MIT alumni. When advance registration passed 300, the committee cut off enrollment (330 actually attended on October 4-5, 1969), scheduled a second seminar at MIT for six months later, and began planning a nationwide rollout. Over the next three years, the committee conducted seminars in eight cities across the United States, using local MIT alumni to run the sessions, with a total of more than 3,000 MIT alumni in attendance, the largest attendance ever generated by the MIT Alumni Association for any program before or since. As far as we know, this was the first effort by any part of MIT to promote entrepreneurial activity.

One of the authors of this report recalls that, over the years, many entrepreneurs have introduced themselves, saying they remember hearing his talks at various MIT Alumni Entrepreneurship Seminars across the country. His first meeting with Neil Pappalardo ’64, with whom he later co-founded Medical Information Technology, Inc. (known as Meditech, but note that the initials are MIT, arising from having four MIT alumni co-founders, plus one from Northeastern University), occurred at an early MIT alumni seminar. Our survey generated many other unexpected testimonials to the direct effects of those and similar, later seminars. Bob Metcalfe ’69, the principal inventor of the Ethernet and later the founder of 3Com, a great success in the computer networking market, reports that after attending an MIT alumni luncheon on starting your own business, he resigned from Xerox’s Palo Alto Research Center, returned to Boston, and established his company with two other engineers. Similarly, the founders of Applicon, now the CAD division of Schlumberger, decided to create their firm after listening to a seminar at MIT Lincoln Lab that reported on the characteristics of the previous Lincoln spinoff entrepreneurs.

The seminars stimulated a variety of responses by local MIT alumni clubs. The parent committee itself organized and distributed directories of alumni who had attended the seminars and who wished to become visible to other MIT would-be entrepreneurs. “Networking” was beginning even before the term was used for that meaning! To continue its mission of encouraging entrepreneurship by MIT alumni and others, the committee also organized and authored a book published in 1974, How to Start Your Own Business, edited by William Putt ’59.
The first significant local follow-on effort was the New York MIT Venture Clinic, which invited early-stage entrepreneurs to present their business plans and progress in an open diagnostic session of club members, aimed at providing feedback and suggesting ideas for improvement to the participating entrepreneurs. A New York alumnus who was spending the year in Boston transferred the clinic approach to a group of eight MIT alumni who were active members of the MIT Club of Boston. The resulting MIT Enterprise Forum of Cambridge flourished from its 1978 founding and still continues with its monthly entrepreneur presentations, with three panelist reviewers per company, to an actively engaged audience of two to three hundred persons at each meeting. Early on, non-MIT alumni were invited to join, creating the opportunity for all relevant elements of the interested Greater Boston entrepreneurial population to commingle and become involved—lawyers, venture capitalists, angel investors, and experienced entrepreneurs, as well as “wannabes.” Periodic major events, such as conferences focused on key emerging technologies or on major issues facing startups and growing companies, supplemented the monthly meetings and enlarged the community. The Cambridge chapter's events calendar for January 2008 illustrates the scope of current activities: January 9, Startup Clinic, featuring two brand-new companies; 10, Get Smart, educational session on term sheets; 17, Concept Clinic, covering issues related to technology commercialization; 21, Special Interest Group on Software Entrepreneurship; 23, Special Interest Group on Digital Media; 24, Start Smart, educational session on Choosing the Right VC. This level of nurturing and networking must be contributing enormously to MIT (and nearby) entrepreneurship.

In 1982, the Cambridge group initiated its Startup Clinic, following a format similar to the big monthly meeting, but focused on very early-stage entrepreneurs who might not be ready to handle a large audience presentation. That monthly Startup session was held in an informal dinner at the MIT Faculty Club, limited to a rotating audience of forty to fifty attendees. In that same year, the first entrepreneurship course offered during MIT’s “open” January Independent Activities Period, “Starting and Running a High-Technology Company,” was organized by the Cambridge Enterprise Forum. Since 1989, that course has been led by Joe Hadzima ‘73, an active participant in the Cambridge Enterprise Forum and recent president and chair of the global MIT Enterprise Forum organization. In January 2008, that continuing course drew about 200 MIT undergraduate and graduate students and staff to daily sessions for one week.

The Startup Clinic's work with early hesitant entrepreneurs has been very rewarding to all who participate. For example, Bill Warner ‘80 was very discouraged and about to pull the plug on his new company, Avid Technology, until he presented at the Cambridge Startup Clinic. After attendees there kicked around and were enthusiastic about his ideas, Warner decided to continue his efforts. Avid went on to change the way film is edited, has won an Oscar and numerous other awards, and has grown to 2007 revenues of $930 million. Eric Giler, a Harvard graduate, was struggling with the beginnings of Brooktrout Technologies when he appeared at the Startup Clinic. He says that the help he received led him to key customers and employees, and new ideas for forging ahead. He later presented at the regular Enterprise Forum meeting, hired a senior management team of MIT alumni, went public, then merged with Cantata Technologies, and eventually sold to Excel.

Stan Rich, then chair of the MIT Enterprise Forum of Cambridge, in 1985 assembled and published materials derived from the sessions to that point in time, “Business Plans that Win $$$: Lessons from the MIT Enterprise Forum,” to provide guidance to nascent entrepreneurs and to further stimulate entrepreneurial activities.

After the mid-'70s, local MIT alumni in other cities began to mimic the Cambridge and New York activities for new and early-stage enterprises, usually with non-MIT participants as well, sometimes co-
sponsored with alumni groups of other universities, such as Cal Tech and Stanford. This movement led to the MIT Alumni/ae Association organizing the nationwide (and now global) MIT Enterprise Forum, Inc., in 1985, now numbering twenty-four chapters, including six in other countries. The national office, housed at MIT, creates frequent televised panel discussions on major trends and topics of interest to entrepreneurs. For example, the January 2004 program, “Innovation at the Interface: Technological Fusion at MIT,” featuring MIT professors and serial entrepreneurs Robert Langer ‘74 (biomaterials) and Rodney Brooks (robotics), had a live audience at MIT of 630, with simultaneous satellite-fed live audiences of an additional 700 in twenty-five cities, and many additional copies downloaded for later replay by local chapters. As an example of the diversity of topics, the September 2008 global forum program focused on the issues affecting female entrepreneurship. Typically, 80 percent of the viewing audience is not MIT alumni, indicating the manner by which the MIT Enterprise Forum is encouraging entrepreneurship all across the country by MIT alumni and many others. Antoinette Muller, director of the national office, indicates that the Association’s 2007 telecast audience was 5,500 people.

There is no way to know precisely how many companies have presented over the years, nor what successes have been fostered by MIT Enterprise Forum endeavors. Well-documented anecdotes abound, including that Michael Dell presented to the Houston chapter while he was still a student at the University of Texas. The MIT Enterprise Forum of Cambridge did an intensive job of trying to assemble its history on the occasion of its twenty-fifth anniversary in early 2003 and was able to document 234 company presentations to its regular monthly meeting from 1981 (prior years’ data are lost). Trish Fleming, director of the Cambridge chapter, estimates that, over the years from 1978 until now, some 700 companies presented to and were helped by the MIT Enterprise Forum of Cambridge alone in its regular sessions or supplemental clinics. The records document a large number of later acquisitions of and public offerings by these companies. On average, about 5,000 total attendees participate annually in the Cambridge meetings. Perhaps an additional 700 startups received support and assistance in the other Enterprise Forum chapters. We have no idea how many of these companies were founded by MIT alumni, MIT-related persons, or others, as today all of the chapters are open in membership to all interested participants, with or without MIT connections.

In the responses from MIT’s limited 2003 alumni survey, we find indications of what aspects of MIT played a role in the entrepreneurs’ founding of their companies. Table 12 shows just those responses that are linked to alumni activities. As we have indicated, the Alumni Regional Clubs were the first MIT channel for presenting to alumni the series of educational seminars on starting a new company. The graduation years of those affected, as shown in the table, nicely correspond to the beginnings of the alumni entrepreneurship programs aimed at earlier graduates as described above, and their continuations in various forms in different alumni regions. Further, as

<table>
<thead>
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<th>Graduation Decade</th>
<th>1950s (N=73)</th>
<th>1960s (N=111)</th>
<th>1970s (N=147)</th>
<th>1980s (N=144)</th>
<th>1990s (N=145)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumni Regional Clubs</td>
<td>5%</td>
<td>5%</td>
<td>3%</td>
<td>12%</td>
<td>3%</td>
</tr>
<tr>
<td>MIT Enterprise Forum</td>
<td>7%</td>
<td>16%</td>
<td>15%</td>
<td>22%</td>
<td>9%</td>
</tr>
</tbody>
</table>

*Respondents could check all relevant categories
documented above, these programs then led to the founding of the MIT Enterprise Forum in 1978, which, over time, grew dramatically and spread geographically, attracting participation from alumni of many classes, as well as many non-MIT participants. (The drop-off in Table 12 in the most recent decade merely reflects the need for more time to elapse before full impact on recent graduates is measurable.) In recent years, current MIT students actively have attended the MIT Enterprise Forum's Cambridge chapter meetings, suggesting that the future impact of the Enterprise Forum is likely to come sooner and also will increase in magnitude.

**Case Example: Brontes Technology**

We end this section by describing some of the dynamics associated with Brontes Technology, an example of a successful outcome from the MIT Enterprise Forum, but clearly one that illustrates the interplay among multiple parts of the MIT entrepreneurial ecosystem, some of which we describe later in this report. The Brontes single-lens 3D imaging technology derived from MIT Deshpande Center research funding to Professor Douglas Hart ’85, which the MIT Technology Licensing Office licensed to Brontes at its formal company startup stage in 2003. Professor Hart was a reluctant entrepreneur who had thought the principal market application would be facial recognition for security. “I came from an era where your job was to be a faculty member and teacher, not to spin out companies,” he said. But, encouraged by the Deshpande Center’s executive director, he attended a 2002 MIT $50K networking event and met the two graduate students who eventually became his company co-founders. They all presented their preliminary ideas to the Cambridge Enterprise Forum Concept Clinic to discuss the commercialization alternatives they were evaluating for the 3D technology. That helped them formulate their business plan for the $50K competition, where they were selected as the runner-up. As the team developed a prototype system, they explored the market opportunities and discovered a large need in dental imaging. After forming the actual spinout company, they returned to present at the Enterprise Forum Startup Clinic, and then received two rounds of seed capital, followed by venture capital funding in 2004. Brontes was scheduling a case presentation to the regular Enterprise Forum when it was purchased by 3M in 2006 for $93 million.

In appraising the impact of the MIT Enterprise Forum, Trish Fleming, director of the Cambridge chapter, observes: “The VCs, the lawyers, the CEOs, the management types all got used to coming here, to learning about technology, to making connections, to finding employees, to providing mentoring to students and new startups through the Forum. As the MIT entrepreneurial ecosystem grew, those relationships were able to grow, too.” The MIT Enterprise Forum, with thirty years of life and now twenty-four chapters nation- and worldwide, inevitably has strongly influenced the culture and entrepreneurial environment not just of MIT, Cambridge, Greater Boston, and beyond, but also has had untold vast effects elsewhere, influencing MIT alumni and many others to form and build new companies.

**The MIT Entrepreneurship Center**

In 1990, Professor Edward Roberts ’57 proposed to Lester Thurow, then dean of the MIT Sloan School of Management, that he support the formation of an MIT-wide entrepreneurship program to serve not just MIT Sloan, but the rest of MIT as well. Its goal would be to educate and develop those who will create, build and lead tomorrow’s successful high-tech ventures. It also planned to increase dramatically, and then provide central coordination and integration of, MIT entrepreneurship classes and student activities. But, unlike nearly all other university entrepreneurship programs, which rested primarily on experience-sharing by entrepreneurs and investors, the proposed Entrepreneurship Center would follow the MIT tradition of “Mens et Manus.” It had to connect rigorous scholarly pursuit of knowledge underlying entrepreneurial success with effective transfer of that
An Evolving MIT Internal Entrepreneurial Ecosystem

knowledge into practice. Thus, Roberts proposed a “dual-track faculty” of “tenure-track” academics and adjunct practitioners, linking entrepreneurial researchers with successful entrepreneurs and venture capitalists, building an ambitious teaching program accompanied by direct coaching and mentoring of student would-be entrepreneurs. Academic faculty whose primary thrust is entrepreneurship but whose discipline base is marketing, or finance, or human resources, for example, would be jointly appointed to their underlying discipline group as well as to the Technological Innovation & Entrepreneurship (TIE) faculty group at MIT Sloan, which would provide overall program coordination. In the past eighteen years, almost all of the leading business schools have adopted this dual-track model for managing their entrepreneurship programs.

With co-sponsorship by MIT Sloan faculty across multiple disciplines, the MIT Entrepreneurship Center (E-Center) was launched with an advisory board consisting of prominent MIT entrepreneurial alumni, including Amar Bose ’51 of Bose Corp., Ken Germeshausen ’31 of EG&G, Bernard Goldhirsh ’61 of Inc. magazine, George Hatsopoulos ’49 of ThermoElectron, Patrick McGovern ’59 of International Data Group, and Ken Olsen ’50 of Digital Equipment Corp. At that time, MIT still offered only one related class, “New Enterprises,” and had only one faculty member doing research in the field.

In 1996, Kenneth Morse ’68 became the first full-time managing director of the MIT E-Center, which then was given a small amount of space near the MIT Sloan classrooms. Filled with cubicles, desks, and filing cabinets, the physical space provided a wonderful home base for housing and nurturing a wide array of entrepreneurship-related clubs and activities, with immediate access to adult coaching and guidance, frequently including an entrepreneur-in-residence in addition to Morse and staff. Over time, the MIT E-Center label has come to represent to many—at and outside of MIT—both that physical space and the broad-based MIT program of education and activities. The rapidly expanding MIT entrepreneurial program has contributed to a dramatic increase in the number and ambition of classes, clubs, conferences, and the resulting breadth and depth of content and contacts that facilitate entrepreneurial behavior. Some have called it a frenzy of entrepreneurship!

Classes

Once the E-Center was underway, its leaders began to create new subjects, attracted existing MIT Sloan faculty to teach them and, when authorized, recruited and hired both practitioners (senior lecturers) and academics (assistant professors and above) into the program. The sole original “New Enterprises” class gradually was expanded into two sections and then doubled again as student interest in entrepreneurship grew across the Institute. While never tabulated, the number of new companies produced by that subject’s MIT alumni is very high, including as examples such companies and graduates as MAST Industries, founded by Martin Trust ’58, and Genentech, co-founded by Robert Swanson ’69. Jon Hirschtick ’83 and his roommate Axel Bichara ’88 both took “New Enterprises,” later they co-founded and sold a CAD company. Hirschtick went on to found SolidWorks, a pioneering company later sold to Dassault.

In 1993, the first new full-time academic faculty member was hired into the Entrepreneurship Program, kicking off the dual-track design and beginning to expand course offerings. In 1994, the MIT Sloan School launched a series of educational-career “tracks” within its Master’s degree program. The MIT Entrepreneurship Center, collaborating closely with the school’s TIE and Marketing faculties, created the New Product & Venture Development Track. NPVD, known by the students as the “Entrepreneurship Track,” quickly became the most popular track for MIT Sloan graduate students, demonstrating the strong, rapidly growing interest in entrepreneurial studies and career paths. All of these “tracks” were dropped a few years later when a major change occurred in the MBA curriculum and were not reinstated until 2006 with the birth of the “Entrepreneurship & Innovation Track” (to be discussed later).
Soon, additional entrepreneurship-focused tenure-track faculty were hired into various MIT Sloan groups, such as international, human resources, technology and innovation, finance, and marketing, with central coordination provided by the TIE group as earlier described. Additional senior faculty from within MIT Sloan and from other MIT departments associated themselves with the growing entrepreneurship educational efforts. A significant number of adjunct faculty, all successful entrepreneurs and/or venture capitalists, also were recruited to bolster the dual-track elaboration, usually as unpaid volunteers eager to share their insights and enthusiasm with the younger entrepreneurial aspirants. By 2001, the number of entrepreneurship subject offerings had grown rapidly to twenty-one and the number of student registrants from all MIT departments had jumped to almost 1,500. Now students across MIT enroll in more than thirty entrepreneurship classes of all sorts, albeit 76 percent of the enrollments are from MIT Sloan, with 16 percent from the MIT School of Engineering.

**Academic Classes in Entrepreneurship**

Over the years, regular MIT “tenure track” faculty have developed and taught several new subjects, focusing on their own PhD training and scholarly research. These classes include such titles as: “Designing & Leading the Entrepreneurial Organization;” “Entrepreneurial Finance;” “Managing Technological Innovation & Entrepreneurship;” “Corporate Entrepreneurship;” “The Software Business;” “Strategic Decision-Making in the Biomedical Business;” “Entrepreneurship without Borders;” and “Competition in Telecommunications.” Each of these subjects provides an underlying disciplinary basis for entrepreneurial actions in a given area. Other subjects also fall into this category.

**Practitioner Classes in Entrepreneurship**

Many of the new subjects that have been developed depend entirely upon the experience of successful entrepreneurs and venture capitalists. These expert practitioners share their real-world insights, built up over years of work, in aspects of entrepreneurship that lack much academic theory. Some of the subjects taught by our extensive part-time practitioner faculty members include: “New Enterprises,” the first course previously described that lays the groundwork for business plan development for new companies; “Technology Sales and Sales Management;” “Early Stage Capital;” and “Social Entrepreneurship” and “Developmental Entrepreneurship,” two subjects that parallel “New Enterprises,” but with a focus, respectively, on the firm motivated by social problem-solving or the context of developing countries. Other subjects also fall into this category.

**Mixed-Team Project Classes**

No doubt both the theory and practice-oriented subjects in entrepreneurship have had great influence on their students, as we have discussed. But, intuitively, we believe the strongest impacts have derived from a cluster of project-oriented efforts, the third category of subjects that we have created over the years since the MIT E-Center began. In these classes, the students organize in teams of four or five, preferably including participants from management and science, and engineering, to tackle real problems in real entrepreneurial organizations. Three subjects constitute the entrepreneurship program’s base in this domain, but we seem to be adding to the entrepreneurship curriculum one or more new subjects of this type every year. Our earliest subject here was “Entrepreneurship Laboratory,” or E-Lab, as it is well-known. Students select from the problems presented by companies that usually are quite young and in the Greater Boston area, although we have violated the distance constraint on many occasions. The intent is to work on “a problem that keeps the CEO up late at night!” With the emerging company CEO as the “client,” the team devotes heavy time for the duration of a semester working on her or his issue, with class time spent on communicating general principles of team management, project analysis, client relationships, some commonly used
tools of market research, and sharing progress reports with each other. The students learn much about teamwork and the issues facing early-stage, technology-based companies. Summer internships and, later, full-time jobs often result from the E-Lab projects. By the way, far more company projects are volunteered than we can accommodate in a single class, indicating the strength of the local network.

Two innovative entrepreneurship faculty members who had been teaching “Entrepreneurship without Borders” developed an approach for globalizing E-Lab. They introduced “Global Entrepreneurship Laboratory,” or G-Lab, in 2000, with the instructional and preparatory parts of the class, including team and company selection, taking place during the latter half of the fall term. During November and December, the teams work with company management to define precise, deliverable objectives and begin substantial background research while on campus. Then, during MIT’s “open” January Independent Activities Period, the teams go off to every part of the world (outside of the U.S.) to work with their chosen companies in three-week “team internship” projects. Finishing up of the projects and evaluation by both company and class occur during February and March. This global entrepreneurial subject rapidly has grown to be the most popular elective course in the MIT Sloan School, with half of the MBA class participating, providing them with a non-U.S. entrepreneurial work experience. In seven years, 185 host companies in eighteen countries have “employed” 810 MIT students in G-Lab projects, including 160 students during the past year. Professor Richard Locke, who co-created and runs G-Lab, says: “Only at MIT Sloan could we move from brainstorming to in-the-field implementation in a few short months. The student teams have offered exciting, imaginative, and—perhaps most important—effective changes in the way startups around the globe conduct business.”

The third mixed-team, real-world project class is “Innovation Teams,” or I-Teams (everything must have a short name!), a “hands-on” team project subject focused on developing commercialization plans for carefully selected MIT faculty research efforts. The idea was conceived at the time MIT launched the Deshpande Center for Technological Innovation (to be discussed later) in the School of Engineering. Each team of business and technical students deconstructs the features of the technology, learns about the intellectual property issues in cooperation with the MIT Technology Licensing Office, scans the potential markets, interviews prospective customers and industry experts, and performs a go-to-market analysis in which it recommends a course of action (e.g., startup, partnership, licensing to industry, further research in the lab). Every team is coached by a seasoned entrepreneur from the Greater Boston community and works closely with the MIT faculty principal investigator of the underlying research project.

Case Example: SaafWater

During I-Teams’ very few years of operation, some of the varied companies that already have emerged following the teams’ class assistance are Avanti Titanium, Hydrophobic Nanomaterials, Myomo, SaafWater, and Vertica Systems. Myomo is discussed in the later section on the Deshpande Center. One of the other projects, SaafWater, built on the research work of Amy Smith ’84, senior lecturer and recipient of a MacArthur Fellowship, who created MIT’s Development Lab program for carrying forward engineering design and devising appropriate technologies for developing countries. The Deshpande Center had funded Smith’s hiring of Sarah Bird ’03 to advance the phase-change incubator research project that would indicate the level of bacterial contamination in village wells. The I-Teams student group developed detailed insights to possible distribution channels worldwide and assisted the principal researchers to enter the 2007 $100K competition. The project reached the finals of the new “development track” and attracted venture capital investment. SaafWater was quickly incorporated and has been operating its first pilot plant in Pakistan since June 2007.
The I-Teams model, initiated by Ken Zolot ’95 as its instructor, has caught on with many students and faculty across MIT. New variations of I-Teams have been encouraged by the MIT E-Center leadership. In collaboration with the MIT Media Lab, “Digital Innovations” was created as a mixed-team projects course to develop and experiment with mobile devices that might impact various markets in developing countries such as Chile. Last year, the E-Center started “Energy Ventures” as another mixed-team, real-world projects subject to encourage the growing student interest in entrepreneurship based on sustainable technologies, with energy ideas and new technologies coming from MIT faculty laboratories and graduate students. In parallel, a coordinated academic subject called “Energy Strategies” was launched to enable a student to build a thorough understanding of energy markets, technologies, competition, and regulatory aspects. “Strategies” and “Ventures” have back-to-back class schedules, so students can do the theory and the practice together. This year, the same model has been applied in a new subject called “The X-Prize,” to bring the excitement of competing in the national X-Prize efforts to solve major problems into a campus-level pursuit of entrepreneurial beginnings. All of these classes involve mixed business-technical student teams in commercialization planning and implementation for state-of-the-art technologies. These classes are also feeding grounds for team business plan proposals for the MIT $100K Competition.

A number of short-but-intense courses relating to entrepreneurship are offered during MIT’s January Independent Activities Period. In 2008, the “Starting and Building the High Technology Firm” course brought about 200 students, mostly from science and engineering, into the MIT Sloan Wong Auditorium daily for one week. Two years ago, we started our first entrepreneurship class restricted to undergraduates. And, this past year, Ken Morse joined with the faculty of the EECS Department to launch the first subject aimed at entrepreneurship for just EECS students. The Neurosciences Department has just started another entrepreneurship subject; another major effort, the Biomedical Enterprise Program, ties together the MIT Sloan School with the Harvard-MIT Health Sciences and Technology Program to encourage students to combine intensive training in clinical medicine with entrepreneurial orientation and subjects. The entrepreneurship education boom at MIT seems to be continuing and accelerating, exposing more and more students to the examples and lessons underlying new-company creation and development.

**Clubs**

*From $10K to $100K and Beyond*

The premier student organization at the outset of the MIT E-Center’s existence was the $10K Business Plan Competition, created in 1990 by the MIT Entrepreneurs Club (largely engineers) and the MIT Sloan School’s New Ventures Association. Its purpose was to encourage students and researchers in the MIT community to act on their talents, ideas, and energy to create tomorrow’s leading firms. Fifty-four teams competed in the first competition; the winner received $10,000 and the runners-up received $3,000 and $2,000 respectively. As an illustration of the MIT entrepreneurial ecosystem at work even in these early days, the finals that first year were conducted as one of the monthly programs of the MIT Enterprise Forum of Cambridge! That practice continued for ten years as the Cambridge Enterprise Forum had the only large audience and community linked to entrepreneurship on the MIT campus. An early achievement of the new E-Center was to secure several years of funding of the grand prize from a generous MIT alumnus and venture capitalist, David Morgenthaler ‘40. His gift freed up the students’ time and energies for building the scale and quality of the $10K competition. With rapid growth occurring, the activity further benefited in 1996 by the memorial gift from the family of the late Robert Goldberg ’65, a successful serial entrepreneur who had returned to MIT to teach part-time. That gift elevated the competition to become the $50K, with $30,000 going to the first-place winner and two $10,000 prizes to the runners-up.
Undergraduate and graduate students from all five MIT Schools and twenty-seven departments and labs have successfully entered the MIT business plan competitions over its eighteen years. Figure 17 shows the sources of entrants to the competitions over these years, with MIT Engineering and MIT Sloan accounting for the majority. Students from Harvard and other local schools, as well as non-students, participate, but each team must include at least one MIT student. Multi-disciplinary teams of technical and business students have proven to be the most successful competitors. These teams bring together the skills necessary for making the bridge between technology and the marketplace, the same lesson taught in a variety of the classes, clubs, and programs throughout the MIT entrepreneurial ecosystem. Panels of experienced entrepreneurs, venture capitalists, and legal professionals judge the business plans.

Tracking alumni companies has been one of the $100K organization’s greatest challenges, even in terms of how many teams competed and who their members were, but especially what happened to them following the competition. We now know that more than 1,500 plans have been submitted over the years by more than 7,500 individuals. Figure 18 shows the number of teams that entered the competition annually, reflecting significant growth of numbers over time, but also reflecting the cyclical effects of the Internet boom and bust.

The refinement process of the competition, its network of mentors, investors, and potential partners, and the cash prizes awarded have helped many of these teams to act on their dreams, and build their own companies and fortunes. Although records are incomplete and tracking is difficult once the students are gone, Karina Drees ’07, lead organizer of the 2006 $100K, was able to document 105 companies formed through the $100K process, of which 22.8 percent already had successfully exited via IPOs or acquisitions of the firms, 23.8 percent are still in business as private companies, 20 percent are no longer in business, and 34 percent have unknown status due to lack of information. Even if we assume total failure of the unknowns, the 46.6 percent (or more) of the companies that have survived or been acquired provide a remarkable success story compared with companies formed nationwide. The $100K companies have received more than $700 million in venture capital funding. At least twenty-four firms have been acquired, of which the seven for which we have figures sold for more than $2.4 billion. The transaction amount was not disclosed in the other cases.
We show in Table 13 the acquisition or IPO exit values of those firms formed out of MIT $100K competitors for which we have reliable data. Testimony from the entrepreneurs indicates that many of the successful companies were based on technologies licensed from MIT. Also, they recognized the importance of the support they received from the vast MIT entrepreneurial ecosystem and, in many cases, had found key people to commercialize their technology through the $100K efforts.

The public data of Table 13 document a value capture for the nine companies of $2.4 billion. This amount, a dramatic underestimation of exit value of all the $100K firms due to our lack of more complete information, represents more than a 550X return on investment on the historical MIT $100K budget and a $150 million per year average return over the life of the student $100K undertaking. At least 2,500 new jobs (no doubt many more) have been created as a result of the MIT student competitions.

We also found three $100K companies that completed successful public offerings, generating more than $350 million at the time of their IPOs. But, by itself, the one company that is still public (the other two were acquired post-IPO) is Akamai

<table>
<thead>
<tr>
<th>Company</th>
<th>$10K-$50K-$100K Date</th>
<th>Valuation at Exit ($ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon Spice</td>
<td>1995</td>
<td>1,200</td>
</tr>
<tr>
<td>(acquired by Broadcom)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct Hit</td>
<td>1998</td>
<td>517</td>
</tr>
<tr>
<td>(acquired by Ask Jeeves)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Webline (acquired by Cisco)</td>
<td>1996</td>
<td>325</td>
</tr>
<tr>
<td>Harmonix (acquired by MTV)</td>
<td>1995</td>
<td>175</td>
</tr>
<tr>
<td>Brontes Technologies</td>
<td>2003</td>
<td>95</td>
</tr>
<tr>
<td>(acquired by 3M)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-Bridge Internet Solutions (acquired by Excelon)</td>
<td>1996</td>
<td>64</td>
</tr>
<tr>
<td>NetGenesis (acquired by SPSS)</td>
<td>1995</td>
<td>44</td>
</tr>
<tr>
<td>Firefly Networks (acquired by Microsoft)</td>
<td>1995</td>
<td>40</td>
</tr>
<tr>
<td>Stylus Innovation</td>
<td>1991</td>
<td>13</td>
</tr>
<tr>
<td>Lexicus (acquired by Motorola)</td>
<td>1991</td>
<td>Not disclosed</td>
</tr>
<tr>
<td>Flash Communications (acquired by Microsoft)</td>
<td>1997</td>
<td>Not disclosed</td>
</tr>
</tbody>
</table>
Technologies, which lost in the 1998 $100K to Direct Hit. It was a $50K finalist founded by MIT faculty and students, based on licensed MIT technology (see later discussion of the Technology Licensing Office) that had market capitalization as of June 18, 2008, of $6.03 billion.

In 1998, the student leaders of the MIT organization created an annual MIT $100K Global Startup Workshop located in a different country each year, in which MIT students bring the lessons they have learned about student team-based entrepreneurship to academic institutions from all over the world. The workshops have been held in Boston, Singapore, Spain, Australia, Italy, China, the United Kingdom, Abu Dhabi, Buenos Aires, and Madrid, heavily attended by campus representatives seeking to replicate the MIT experiences. This student-initiated and -run effort has helped to create competitions worldwide modeled after the MIT activities. Despite this, Inc. magazine said that “[the MIT $100K] is more equal than all the others!” To illustrate, last year’s winning MIT team, SteriCoat, consisting of a 2006 MIT Sloan Fellow alumnus and his teammates, entered various business plan competitions as a way of raising additional funds to launch their business. In addition to winning the MIT $100K, the team took first place in the Oxford University Competition and the Harvard Biotechnology Competition, and second place in the Rice Business Plan Competition.

New MIT entrepreneurial endeavors that are linked to the $100K continue to be born. In 2005, the Cambridge MIT Enterprise Forum chapter launched its Ignite Clean Energy Business Plan Competition, founded and chaired by two MIT alumni. For the first two years, nearly all of its events were held on the MIT campus. In 2006, an alumnus who had volunteered for that competition took the concept with him when he moved to the Bay Area of California and founded the California Clean Tech Open, with the MIT Club of Northern California and the MIT Enterprise Forum of the Bay Area as the sponsors. In 2007, a spectacular advance occurred with an additional prize of $200,000 provided by the U.S. Department of Energy and NSTAR for winning business plans focused on “clean energy,” but now administered by the MIT $100K.

In spring 2006, the competition incorporated the Entrepreneurship for Development Competition (plans for new businesses aimed at solving socio-economic problems in developing countries) under its umbrella. This action inspired the student organizers to re-brand from the previous MIT $50K title to the MIT $100K, offering two grand-prize winners $30,000 each and the four runners-up $10,000 each. A new $10,000 prize has just been established for the best plan submitted in aero-astro, new prizes are expected for the life sciences competitive track, and inevitably, additional targeted entrepreneurial competitions will happen in the future, further stimulating campus-wide initiatives. The 2008–2009 competition was run with seven parallel tracks, with major prizes to be awarded for the winners of each track.

**Lots of Clubs**

The array of clubs tied to entrepreneurship is impressive, and forms a key part of the MIT entrepreneurial ecosystem. Students at all levels, from undergrad to PhD and post-doctoral, across all MIT departments, actively participate. They contribute immeasurably to creating the unique “passion for entrepreneurship” that now seems apparent throughout MIT. Many of these clubs are housed in small spaces within the MIT E-Center; others just use the mailing lists, and get advice and help there. The clubs often represent interest groups around particular areas of technology, such as the Astropreneurs Club, BioPharma Business Club, Energy Club, Mobile Media Club, NeuroTech Club, and the NanoTech and TinyTech Clubs. All of them have speaker programs with venture capitalists, MIT faculty, and related entrepreneurs helping to educate and connect the members to early-stage firms and to new ideas in their fields. Frequently they organize major meetings and colloquia.

Other clubs are more focused on stimulating entrepreneurship per se, or providing connections for prospective entrepreneurs. For example, Sloan
Entrepreneurs promotes networking events within the MIT Sloan School, with the Greater Boston community, other local MBA programs, and established Boston organizations. Tech Link started in 1999 as a joint venture between the MIT Sloan Senate and the MIT Graduate Student Council to generate social interaction across school and departmental lines for personal and professional development. With 1,200 members, it has become the largest student organization at MIT. It organizes many major events each year, including “treks” to visit early-stage companies in different technological fields. The MIT Innovation Club centers its activities on helping its members to generate new ideas and commercialize new technologies. And there are many others.

One of the most vital and successful student activities is the Venture Capital/Private Equity Club. Evolving from a small interest group with local speakers, the group now organizes and runs two major nationwide conferences, the MIT Venture Capital Conference in the fall and the MIT Private Equity Conference in the spring, wholly managed by MIT students. The hundreds of attendees from the professional community, as well as MIT students, make invaluable contacts for their entrepreneurial ventures and for recruiting opportunities.

Conferences

In addition to facilitating the major conferences of the VC/PE Club, the E-Center goes outside of MIT’s boundaries to produce several key conferences that further enhance the environment for new-firm formation. Its most visible Cambridge event is the annual so-called “Bio Bash,” more formally known as the “Celebration of Biotechnology in Kendall Square.” Last year, more than 850 registered for the event, including 150 founders, CEOs, and board members. As with the many other seminars and receptions organized by the MIT E-Center, the purpose is to bring together students, entrepreneurs, venture capitalists, and others who will enhance networking and communications that might stimulate additional entrepreneurship. With MIT in the center of an intensive biotechnology cluster, including the MIT-related Whitehead and Broad Institutes, creating the Bio Bash was a natural opportunity. In recent years, the program has started with a professional colloquium on some major topic of importance to the biotech community, providing a “legitimate” excuse for some executives to travel to Cambridge from Europe or the West Coast just for the day.

Each semester, the E-Center organizes a major networking reception in the MIT Faculty Club to honor the CEOs of past and present “E-Lab companies,” i.e., those that have hosted student teams from the Entrepreneurship Lab classes. The current students always are given prominence at this event to try to promote summer internships and permanent jobs with the heads of the high-tech companies and their many venture capital investors who regularly attend the reception. For the past three years, the spring “E-Lab Bash” has featured the award of the Adolf Monossion ’48 Prize for Entrepreneurship Mentoring, given to recognize a person or group who has been outstanding over the years in nurturing and assisting young entrepreneurs.

Over several recent years, MIT had a partnership with the United Kingdom called the Cambridge MIT Initiative. The transfer to British universities of insights from the MIT E-Center and the $100K were key components of the relationship. Annually in London, the E-Center organized a black-tie networking event that drew 500 people to build entrepreneurial ties. Attendees included the student leadership and the year’s winning team of the MIT $100K competition. Even the Brits were surprised at their own enthusiasm for such rousing get-togethers. Observers at any of these conferences/receptions/parties could see that the real benefits were in the numerous one-on-one conversations that were happening between job seekers and job providers, between enterprises looking for money and investors searching for good targets, and between those with new ideas and those with previously developed skills wanting their next chance.
Impact of the MIT Entrepreneurship Center and Network

Our 2003 MIT alumni survey sought measures of MIT-related factors that influenced the founding of the new companies. In Table 14, we show several dimensions that directly link to E-Center efforts. Clearly, MIT’s entrepreneurial network was seen as a critical influencing force even fifty years ago, but its strength has grown dramatically to the point that half of the most recent entrepreneurs see the network as a key factor in the founding of their companies. Appropriately, the MIT E-Center itself and the $10K-$50K-$100K Business Plan Competition have had essentially no perceived influence on alumni entrepreneurs until the past decade or so, when alumni have had the opportunity to engage with them. Prior to the founding of these two entities, only a few graduates of MIT classes had become connected with the E-Center, perhaps as E-Lab company CEOs or as $100K judges. But, during their relatively short lives, both the E-Center and the $100K have jumped into prominence as influences on those students who later became company founders. Other survey results indicate that the more recent alumni entrepreneurs, in particular, see extracurricular and social activities as accounting for the team formation of about 60 percent of the new firms, with an increase in the percentage of the startup ideas also coming from networking. The growth of classes, clubs, conferences, and their informal spinoffs has altered the internal environment of MIT relating to these entrepreneurial movements.

Bob Metcalfe ’68, Ethernet inventor, founder of 3Com, and now a partner in Polaris Ventures, is a constant observer of MIT. “It’s not just that MIT’s entrepreneurial environment flourishes under its institutional commitment to technology transfer,“ he said. “It’s also that MIT includes both ‘nerds’ and ‘suits.’ Divergent life forms, yes, but necessary to and working together at MIT on entrepreneurial innovation. And what keeps MIT’s entrepreneurial ecosystem accelerating is that nobody is in charge. There are at least twenty groups at MIT competing to be the group on entrepreneurship. All of them are winning.” Testimony supporting this effect also is presented by the 2003 results shown in Table 15. There we see that, over five decades, the importance of faculty and research to new enterprise creation has been vital, but more or less constant, whereas the perceived influence of other students on venture founding has grown enormously, to the point that it is the dominant single perceived influencing factor found in our studies. The internal network of relationships, especially student-to-student, has become king!

Technology Licensing Office

The history of the MIT Technology Licensing Office traces the evolution of the MIT entrepreneurial culture and ecosystem. In 1932, the MIT Committee

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### Table 14

<table>
<thead>
<tr>
<th>Graduation Decade</th>
<th>1950s (N=73)</th>
<th>1960s (N=111)</th>
<th>1970s (N=147)</th>
<th>1980s (N=144)</th>
<th>1990s (N=145)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIT Business Plan Competition</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>3%</td>
<td>30%</td>
</tr>
<tr>
<td>MIT Entrepreneurship Center</td>
<td>3%</td>
<td>1%</td>
<td>2%</td>
<td>1%</td>
<td>12%</td>
</tr>
<tr>
<td>MIT’s Entrepreneurial Network</td>
<td>26%</td>
<td>25%</td>
<td>32%</td>
<td>40%</td>
<td>30%</td>
</tr>
</tbody>
</table>

*Respondents could check all relevant categories
Entrepreneurial Impact: The Role of MIT

An Evolving MIT Internal Entrepreneurial Ecosystem

On Patent Policy was formed to address issues of ownership of inventions and discoveries stemming from research done at the Institute. In 1945, the Patent, Copyright and Licensing Office was established as part of the MIT Division of Sponsored Research, one of the earliest university efforts of its type in America. It became a separate entity and was renamed the Technology Licensing Office in 1985. As its formal function had been to facilitate patent applications, and to execute copyright and patent licenses with industry, government agencies, and other research institutions, the Patents office had been dominated by lawyers. With the 1985 entry of John Preston as director and Lita Nelsen ’66 as associate director, the lawyers were ousted and the TLO dramatically reoriented toward playing a far more active role in technology transfer. In that initial TLO year, the office put together eight to ten agreements with industry and registered approximately 120 invention disclosures. The latest figures average eighty to 100 agreements and about 500 disclosures per year, now under Nelsen’s directorship for many years. The current TLO Web site describes its mission as “to benefit the public by moving results of MIT research into societal use via technology licensing, through a process that is consistent with academic principles, demonstrates a concern for the welfare of students and faculty, and conforms to the highest ethical standards.” It assists MIT inventors in protecting their technology and in licensing that technology to existing companies and startups.

The TLO’s licensees fall into three categories—well-established (large) companies, small (often local) companies, and startups. Although the TLO’s licenses, in numbers, divide roughly evenly into the three categories, the majority of the exclusive licenses—the ones that fulfill TLO’s mission to encourage the development of truly innovative technologies requiring significant investment—go to startup companies.

The primary reason for the TLO’s strategic dependence on startup companies has been the reluctance of large companies to invest in “university-stage” technologies, because the risk and cost of development is high and the time to market is long. In many fields (e.g., pharmaceuticals) the large companies have become dependent on startups to bring university-stage technology into proven product concepts, after which the large companies license the product from the startup or acquire the young company. But the TLO’s effectiveness in this strategy depends on venture investors’ willingness to invest in early-stage technology, somewhat scarce in recent years following the burst of the “dot-com” bubble and very scarce in the current severe economic downturn. The TLO strives to maintain a “level playing field” among many venture capital firms to attract them toward MIT startup opportunities by communicating fairness and openness.

<table>
<thead>
<tr>
<th>Graduation Decade</th>
<th>1950s (N=73)</th>
<th>1960s (N=111)</th>
<th>1970s (N=147)</th>
<th>1980s (N=144)</th>
<th>1990s (N=145)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>26%</td>
<td>24%</td>
<td>38%</td>
<td>50%</td>
<td>66%</td>
</tr>
<tr>
<td>Faculty</td>
<td>48%</td>
<td>42%</td>
<td>37%</td>
<td>28%</td>
<td>37%</td>
</tr>
<tr>
<td>Research</td>
<td>32%</td>
<td>32%</td>
<td>30%</td>
<td>26%</td>
<td>33%</td>
</tr>
</tbody>
</table>

*Respondents could check all relevant categories

Table 15

MIT Factors Important to Venture Founding (from limited sample only)

some venture capitalists and even more angel investor groups still are interested in early-stage technologies, even in difficult economic times.

Beyond the real incentives to faculty of having their ideas brought to fruition and use in the real world, some faculty, graduate students, and post-docs also participate on an ongoing basis in the companies that are started with their technologies, the faculty usually as advisors or board members, the students (once they are alumni) often as co-founders and full-time leaders of the firms.

A typical deal that TLO structures provides technology exclusivity in a clearly specified and limited field of use (to provide clear economic incentives to the licensee), a modest license fee ranging from $25,000–$100,000, and a royalty of 3 percent to 5 percent of the sales that arise from the licensed technology, often with a minimum annual royalty that escalates over time. If and when royalties are collected from the licensee, they are distributed (after reimbursement of TLO expenses) one-third to the inventors, one-third to the inventor's department, and one-third to MIT's general funds.

For startups, instead of cash up front and in lieu of some of the royalties, the TLO usually takes a small equity ownership that is less than 5 percent of the new firm. By its active engagement with faculty and other entrepreneurs, as well as venture capitalists, the TLO is a vital participant in MIT's entrepreneurial ecosystem. Figure 19 shows the number of startup companies it has licensed with MIT technology in each of the past ten years, 1998–2007.

United States university licensing data are available for many years from the Association of University Technology Managers. In AUTM's latest survey, which covers 2006 (AUTM, 2007), MIT's twenty-three licenses rate it second only to the entire University of California statewide system. Table 16 shows all of the U.S. universities that licensed ten or more startups during 2006. For the 189 respondents to that AUTM survey, the average number of licenses per institution was four. In 2005, MIT was first in the nation with twenty startups being licensed, while the University of California system licensed nineteen, Cal Tech assisted sixteen, and the University of Florida provided licenses to thirteen. No other institution had licensed ten or more new firms during 2005.

Over many years, MIT almost always has been first among U.S. universities in technology transfer to new enterprises. We do not know how many of these licenses go to companies that are not MIT-alumni founded. Nor do we know how much “leakage” might occur with unlicensed MIT technology becoming the basis for new-firm

![Figure 19](image-url)

**Figure 19**

Number of Startups Licensed by MIT TLO, 1998–2007
formation. Thus, the numbers cited here and in our alumni figures again inevitably understate overall entrepreneurial impact of MIT technology.

Sometimes the time required for such early-stage licensed technology to have economic impact is quite long. For example, Cubist Pharmaceuticals was founded by two MIT faculty members with an MIT license in 1992. After long struggles, the company finally has advanced to the point that it is anticipating $500 million in 2009 revenues, a long haul to successfully bring new science to the marketplace.

Beyond their formal roles, the TLO staff members, due to their organizational location and personal expertise, also actively contribute in their “spare” time to MIT classes and student activities. These include participation in sponsorship and judging of the $100K Business Plan Competition, active involvement with the MIT Enterprise Forum, and guest lectures on patents and licensing in a number of courses, both undergraduate and graduate, and clubs.

Even prior to the Venture Mentoring Service (to be discussed later), which it now also helps, the TLO provided “open-door coaching” for any student thinking of starting a business, whether through an MIT license or not. Several dozen students per year participate. That coaching now includes having TLO staff take on roles as project advisors and i-Team Catalysts for the Deshpande Center. All of these endeavors tie the knowledge and connections of the TLO to the rest of MIT’s internal efforts at stimulating and aiding entrepreneurship. Note in Table 17 the increasing evidence over time of visibility and perceived impact of the TLO on venture formation, despite the fact that only a very small fraction of the alumni entrepreneurs surveyed in 2003 employed MIT-licensed technology in their new enterprises.

**Case Example: A123 Systems**

No doubt at least one interesting story can be told for each startup the TLO licenses. A most recent one illustrates primarily the formal role of the TLO in helping new companies to be created and MIT technology to go to market. It also again illustrates

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**Table 16**

Primary Universities Doing Startup Licensing, 2006*

<table>
<thead>
<tr>
<th>University</th>
<th>Startups Licensed</th>
</tr>
</thead>
<tbody>
<tr>
<td>U. California system</td>
<td>39</td>
</tr>
<tr>
<td>MIT</td>
<td>23</td>
</tr>
<tr>
<td>U. Utah</td>
<td>17</td>
</tr>
<tr>
<td>Purdue</td>
<td>14</td>
</tr>
<tr>
<td>SUNY</td>
<td>12</td>
</tr>
<tr>
<td>U. Colorado</td>
<td>10</td>
</tr>
<tr>
<td>U. Florida</td>
<td>10</td>
</tr>
<tr>
<td>U. Washington</td>
<td>10</td>
</tr>
</tbody>
</table>

* Compiled by the authors from AUTM data

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**Table 17**

Technology Licensing Office Importance to Venture Founding (from limited sample only)

<table>
<thead>
<tr>
<th>Graduation Decade</th>
<th>1950s (N=73)</th>
<th>1960s (N=111)</th>
<th>1970s (N=147)</th>
<th>1980s (N=144)</th>
<th>1990s (N=145)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Licensing Office</td>
<td>1%</td>
<td>0%</td>
<td>2%</td>
<td>4%</td>
<td>11%</td>
</tr>
</tbody>
</table>

*Respondents could check all relevant categories

---

the power and workings of the overall MIT entrepreneurial ecosystem. In spring 2001, Ric Fulop ’06, a serial entrepreneur who had been involved in five startups by the time he was twenty-five years old, was looking for his next opportunity. Howard Anderson, also a serial entrepreneur who teaches the “New Enterprises” subject and several other MIT entrepreneurship classes and was founder of the YankeeTek venture capital firm, had participated in investments in two previous Fulop ventures that had lost $10 million. But Anderson had deep admiration for Fulop and gave him space in his office to help Fulop think through his next undertaking. After a few months of research into the energy business, and then narrowing to battery technology, Fulop scanned the country in search of technological alternatives, including reviewing MIT TLO’s database on MIT technologies. As a result, Fulop approached Professor Yet-Ming Chiang ’80 with his idea of using carbon nanotubes as a basis for setting up a new battery company. Chiang quickly convinced Fulop that Chiang’s lab had more interesting battery R&D underway and the two of them began serious discussions. As they looked for a third partner to run engineering, Chiang introduced Fulop to Bart Riley, who incidentally had been an early employee of American Superconductor, an earlier MIT spinoff that Chiang had co-founded in 1987. By September 2001, Fulop, Chiang, and Riley had decided to form a new battery company, A123 Systems, and began to negotiate with the TLO (leaving Chiang out of the discussions to avoid conflict of interest) for exclusive rights to Chiang’s MIT battery developments. All went smoothly with MIT and, by December 2002, the company had completed its first round of venture capital funding from Sequoia Capital, Northbridge Ventures, YankeeTek, and Desh Deshpande (see later discussion of the Deshpande Center), who also became chairman of the A123 board. The A123 story since then has been magical, with more than $250 million in venture funding by December 2008, six manufacturing plants in China and Korea, more than 1,800 employees, and more. A123 is moving rapidly forward with multiple products in its three target markets, including cordless tool batteries (its first product application was the launch of a new line of professional tools by the DeWalt division of Black & Decker), multi-megawatt batteries for renewable integration into the electric grid, and batteries for transportation (with more than nineteen models of hybrid and plug-in vehicles with major American and European automakers under development). A123 already has become one of the world’s leading suppliers of high-power lithium ion batteries.
Recent MIT Institutional Broadening and Growth

During the last few years, three major institutional additions at MIT have contributed immediately to the development and launching of new companies, and strongly to the overall MIT entrepreneurial ecosystem. They are the Venture Mentoring Service, the Deshpande Center for Technological Innovation, and the MIT Sloan Entrepreneurship & Innovation MBA Program, all of which we discuss below.

MIT Venture Mentoring Service

The MIT Venture Mentoring Service was proposed in 1997 as a joint venture of the MIT Sloan and Engineering schools, with the MIT E-Center expected to be its host. But, as with many new ideas, it took time, key people, and money to actually get underway. As a result of generous donations by two MIT alumni, Alexander Dingee ’52 and Professor David Staelin ’60, VMS finally got started in 2000, its premise being that a fledgling business is far more likely to thrive when an idea, a good business plan, and an entrepreneur are matched with proven skills and experience. VMS has an office in MIT’s main building complex, under the MIT Dome, and a small, full-time staff directed by Sherwin Greenblatt ’62, the first employee and later president of Bose Corporation, aided by a large number of part-time volunteers. It provides free and, hopefully, objective advice and assistance to anyone affiliated with MIT—student, staff, faculty, alumnus/a—who is considering the possibility of starting a new company.

As indicated in Table 18, between VMS’s founding and mid-2007, more than 900 men and women participating in nearly 500 contemplated ventures have received guidance and coaching. Prospective entrepreneurs often come to VMS at very early stages in their idea process—usually before there is a business plan, a strategy and revenue model, a team, or any funding.

<table>
<thead>
<tr>
<th>Table 18</th>
<th>Some VMS Data (mid-2007 report)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventures served since 2000</td>
<td>469</td>
</tr>
<tr>
<td>Entrepreneurs served</td>
<td>932</td>
</tr>
<tr>
<td>Companies formed</td>
<td>88</td>
</tr>
<tr>
<td>Funding raised by companies</td>
<td>$350M +</td>
</tr>
<tr>
<td>Current mentor pool</td>
<td>121</td>
</tr>
<tr>
<td>Mentoring hours (just in the past 12 months)</td>
<td>more than 9,000</td>
</tr>
</tbody>
</table>

The VMS staff and volunteers don’t screen to pick winners; rather, VMS’s mission is to use any plausible idea as the focus for education on the venture creation process. The process of forming a viable company can take anywhere from a few months to as much as five years. Eighty-eight new companies, or more than 17 percent of the ventures that have signed up as VMS “clients,” already had formed operating companies by mid-2007.

Ultimately, many of the prospective entrepreneurs find their ideas are not practical as ventures, but they have learned much about being entrepreneurs and forming ventures. Some of them return with another venture concept that does turn into a company. The ventures served during the first seven years of VMS have raised total funding that significantly exceeds $350 million. This includes venture capital and angel investments, grants, and other seed capital.

VMS’s mentor pool has grown from its founding group of seven in 2000 to more than 100 mentors actively engaged in the program and working with entrepreneurs. Another twenty mentors serve as ad hoc specialist resources.

The Venture Mentoring Service’s major contributions seem to come from the “no-strings-
attached” advice and guidance of experienced mentors. This encourages entrepreneurs to make more educated, thoughtful, and informed decisions, thereby enhancing their chances for success. Typically, VMS builds a long-term relationship that significantly influences the startup. Among the ventures that have been mentored by VMS along the path from idea to operating enterprise, showing the variety of markets and technologies being tackled, are:

- **Brontes Technologies, Inc.** Described previously in the section on the MIT Enterprise Forum, Brontes developed and commercialized a revolutionary single-lens 3D imaging technology, which it applied to the dental imaging market. The company was acquired by 3M in October 2006.

- **Corestreet, Ltd.** Infrastructure and software for security and smart credentials.

- **Gaterocket, Inc.** Advances the electronic design automation industry’s ability to develop advanced FPGA semiconductors.

- **Greenfuel Technologies Corporation.** Uses algae forms to clean air by recycling carbon dioxide from industrial facilities and turning it into bio-fuels.

- **Interactive Supercomputing, Inc.** Software platform delivering interactive parallel processing to the desktop, dramatically speeding up solutions to complex industrial and governmental research and operational problems.

- **Myomo, Inc.** Described later in the section on the Deshpande Center, Myomo (previously called Active Joint Brace) is a pioneer in neuro-robotics, a new class of non-invasive medical device technology combining neuroscience and robotics to restore mobility after neurological dysfunction. The company created the first portable, wearable robotic device to help stroke patients relearn how to move by enabling them to initiate and control movement of their partially paralyzed arms.

- **Smart Cells, Inc.** Making use of a polymer-based dosing technology developed at MIT by its co-founder, SmartCells is developing a once-a-day, self-regulating, injectable formulation for treating diabetes.

- **Vela Systems, Inc.** This mobile software for field activities in construction and capital projects management leverages capabilities of tablet PCs to deliver construction projects faster, with higher quality and lower risk. Vela now is used on more than 300 projects from Las Vegas to Dubai.

Table 19 below, showing essentially no perceived importance of VMS to venture founding, is actually quite reassuring from a research reliability perspective. Given that the Venture Mentoring Service was operational only in 2000 and the survey was conducted in 2003, it would have been disturbing if more than one or two respondents cited VMS as an influencing factor. But VMS, its founders, and key leaders were recognized by being awarded the Adolf Monosson Prize for Entrepreneurship Mentoring by the MIT E-Center in 2007.

**MIT Deshpande Center**

On January 3, 2002, MIT announced the creation of the Deshpande Center for Technological Innovation, funded by a magnanimous gift of...

<table>
<thead>
<tr>
<th>Graduation Decade</th>
<th>1950s (N=73)</th>
<th>1960s (N=111)</th>
<th>1970s (N=147)</th>
<th>1980s (N=144)</th>
<th>1990s (N=145)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venture Mentoring Service</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
</tr>
</tbody>
</table>

*Respondents could check all relevant categories*
Recent MIT Institutional Broadening and Growth

$20 million from Jaishree Deshpande and Desh Deshpande, whose most recent entrepreneurial achievement was as co-founder and chairman of Sycamore Networks. Housed in the School of Engineering, the Deshpande Center funds leading-edge research on novel technologies in collaboration with the New England high-technology entrepreneurial and venture capital communities. Via those linkages, the Center’s unique thrust is to identify emerging MIT technologies that are especially likely to be able to be commercialized, and to accelerate and improve that process of movement to market. It thus seeks to bridge the innovation gap between idea and market.

Dr. Deshpande said: “MIT has always provided a fertile ground where its students and faculty can break through technology barriers, fuel new areas of research and development, and fundamentally transform whole industries…Our hope…is to give creative new entrepreneurs…the ability to translate their ideas into innovative companies and products.” The Center supports a wide range of emerging fields, including biotechnology, biomedical devices, information technology, new materials, tiny tech, and energy innovations. It provides Ignition Grants of up to $50,000 each to enable exploratory experiments and proof of concept, and then provides Innovation Program Grants of up to $250,000 each to advance ideas past the “invention stage.” Professor Charles Cooney ’67 has served as the Center’s director since its founding.

At the outset, the Deshpande Center was announced as linked to the MIT E-Center, most strongly evidenced by the establishment two years later of the jointly taught “Innovation Teams” subject, with mixed-student teams across MIT departments focusing on developing commercialization plans for Deshpande research projects.

The Deshpande Center engages in numerous activities to seek out new faculty participants and to aid those funded to gain visibility and networking assistance from the relevant community outside of MIT. The Center has recruited experienced entrepreneurs and venture capitalists to serve as Catalysts who work closely with each research project to provide guidance about market and commercialization issues. Senior staff of the MIT TLO work closely with the Catalysts to assist the project principal investigators, as well as to help the I-Teams that get formed around many of those projects. One of the largest Deshpande activities with several hundred in attendance is the annual, one-day IdeaStream Symposium, featuring key MIT faculty presenters, venture capital panelists discussing the current “hot” fields, and display booths with chart sessions for all of the currently funded Deshpande grants.

From its founding in 2002 through the end of 2007, the Center had received about 400 research proposals from several hundred MIT faculty. It had provided $8 million in grant funding to eighty projects. Follow-on research funding of the MIT projects, from both government and corporations, amounts to more than $3.5 million. Thus far, fifteen companies have been formed, gaining more than $100 million in outside capital investment and employing more than 200 people.

Case Example: Myomo

A few of the significant spinouts of the Deshpande Center are Brontes Technologies (previously described in the section on the MIT Enterprise Forum), Myomo, Pervasis Therapeutics, Q-D Vision, and Vertica Systems. One example of Deshpande Center commercialization is Myomo, started with Deshpande funding in 2002 as the “Active Joint Brace” research project of Professor Woodie Flowers ’68. The case again reflects the strong interrelationships among various parts of the MIT entrepreneurial ecosystem. The project’s evolution from academic research toward commercialization may be seen in the descriptions of the work used at various times. The research group’s initial self-description was: “Our research group aims to create a wearable, affordable, unencumbering exoskeleton that augments human physical capability by working in parallel with existing musculature.”
After its first pass with an I-Teams group effort, the work was described as: “Active Joint Brace is an orthopedic joint brace combined with a powered assist mechanism modulated by a neurological sensor.”

By the end of the semester with their I-Teams group, they were introducing their technology by pointing out: “Ten million of the twenty-one million Americans living with disabilities have difficulty lifting a light object such as a fork or a toothbrush.” At that point in 2004, the team, consisting of MIT faculty, students, and an alumnus, plus a Harvard student, entered the $50K Business Plan Competition and won the Robert Goldberg Grand Prize of $30,000. By January 2006, the research project was finished and Myomo Inc. (short for My Own Motion) was born. It received FDA clearance to market its first product in July 2007. In November 2007, it received the Popular Science “Best of What’s New” Award for its NeuroRobotic Technology Innovation.

MIT Sloan Entrepreneurship & Innovation MBA Program

Entrepreneurship & Innovation (E&I) is a new option within the two-year MIT Sloan MBA Program, made available for the first time to selected applicants in the entering MBA Class of 2008. The program focuses on teaching committed grad students how to launch and develop emerging technology companies. It builds a select lifetime cohort of collaborative entrepreneurial MBA classmates and leads to an MIT Sloan Certificate in Entrepreneurship & Innovation, in addition to the MBA degree. The E&I curriculum heavily emphasizes team practice linked to real-world entrepreneurial projects, balances theoretical and practitioner education, and provides a thorough exposure to the many building blocks of an entrepreneurial career. Perhaps not surprising to some, more than one-third of the entering MBA students applied for admission to this new opportunity when it was announced in June 2006, but the 125 had to be screened down to fifty first-year students to manage program introduction. About one-quarter of the MIT Sloan MBAs now enter this entrepreneurship concentration.

The E&I program begins with the standard first-semester MIT Sloan MBA core, permitting the entrepreneurship cohort to become fully integrated with their classmates in all activities. But during that first term, the E&Is also take an overview course that introduces them to all aspects of entrepreneurship education and practice at MIT. Both academic and practitioner faculty meet with the group, as do the heads of the MIT VMS, TLO, Deshpande Center, and several local entrepreneurs and venture capitalists, creating special access to the MIT entrepreneurial ecosystem. The semester is followed almost immediately by an intensive one-week group trip to Silicon Valley, arranged by the MIT E-Center. The class visits leaders of multiple venture capital firms and meets in small groups with a large number of carefully selected, early-stage high-tech firms in the life sciences, medical technology, software, information technology, advanced materials, and new energy fields. During the following three semesters, the E&I program requires students to participate in at least one MIT $100K team (described above) and to choose several additional subjects from a restricted menu of entrepreneurial electives (including E-Lab, G-Lab, and I-Teams, all described previously) that prepare them to start and build companies, while letting them enroll in other broadening MIT and MIT Sloan courses such as finance or marketing.

One of the students in the inaugural class, Nikhil Garg, MBA ’08, described his experience: “I could have spent my entire two years on campus meeting like-minded entrepreneurs here and there. But everyone in this class wants to start a company. It’s so much easier to facilitate ideas and business relationships with other MBAs and techies in this type of environment.” Will O’Brien, MBA ’08, spearheaded weekly, thirty-minute “Open Mic” sessions to encourage his classmates to practice their pitches, preparing them for future encounters with venture capitalists. “The caliber of ideas has been phenomenal,” says O’Brien. “They’ve ranged from new ventures in wind energy, developmental
entrepreneurship, media, and even beer manufacturing.” In December 2008, O’Brien launched a Web 2.0 company that he began with an E&I classmate during their second year in the program.

Half of the inaugural group previously had founded their own or been part of startup companies. Many more company formation initiatives began even within the first term of the students’ arrival on the MIT campus. A group of the first-year E&I class demonstrated its entrepreneurial savvy by winning the UC-Berkeley School of Business “Media Case Competition,” sponsored by Yahoo!, and took home a check for $10,000. Another first-year E&I participant became part of an African-American team that won the $10,000 first prize at the 2006 Whitney M. Young New Venture Competition at the Wharton School, the three finalists being MIT, Stanford, and UCLA. One more classmate was a $1K winner and another a finalist in the MIT $100K competition. In November 2008, with three E&I classes underway, the evidences continue to grow of MBA students’ strong desires to create their own new firms, despite the E&I program leadership’s guidance that they first gather more real-world experience working in startups before initiating such actions on their own. Twenty-five ’08 MBA graduates, the first year of E&I program completion, started their own companies before or upon graduation from MIT Sloan, three times the number of immediate startups from the Class of 2007. This may be an early sign of the E&I track’s impact on its own group as well as on other entrepreneurial classmates.
Conclusions: Enhancing the Role of Research/Technology Universities in an Entrepreneurial Economy

Universities that are strong in research and technology are at the forefront of knowledge creation and potential application. When the university is able to couple this capability with the inclination and resources needed to connect ideas and markets, impressive possibilities exist for generating entrepreneurship-based economic impact at the local, as well as national and global levels. Most important in making this transformation is having the institution’s leadership adopt the will to accomplish this. Numerous changes are needed in most universities over an extended period of time in rules, regulations and, more important, attitudes and institutional culture. None of these will be accomplished without strong and committed university leaders.

The MIT history described in this report provides numerous and detailed examples of how one major institution achieved significant entrepreneurial impact over its first 150 years. Early examples of engaging the academic with the real world, even including entrepreneurial actions by senior and respected faculty and university officials, did much to capture the attention of more junior faculty members, as well as students and alumni, to the legitimacy of technology transfer and commercialization. Big differences between institutional histories of entrepreneurial output no doubt are explainable to a great extent by this distinction alone in leadership roles and behavior. MIT’s history suggests that the appropriateness of rules and regulations needs to be assessed carefully to be sure that they do not create barriers to faculty participation in industrial consulting and, more vitally, that they do not hinder faculty initiatives in new companies’ formation. A shift from barriers toward incentives will take much time to occur in most organizations, and will be accelerated if advocates for entrepreneurship pay strict attention to establishing and enforcing guidelines against conflicts of interest.

Until quite recently, MIT had followed a “hands-off” approach toward entrepreneurial engagement, in contrast with many other universities in the United States and abroad. MIT has neither created an internal incubator for ventures nor a venture capital fund to make life easier for prospective startups. Those facts have permitted MIT to avoid degrees of internal conflict and occasional embarrassments that have plagued other academic institutions that have tried to hurry the entrepreneurship process. But MIT has had the advantage of a surrounding community that essentially has provided those functions, as well as other aspects of a supportive infrastructure for new enterprises. In less well-endowed neighboring circumstances, a university may have to supply with great care the active help and at least some funding to get entrepreneurial ventures off the ground.

Instead, MIT has relied internally on growing faculty, student, and alumni initiatives, especially during the most recent thirty years, to build a vibrant ecosystem that helps foster formation and growth of new and young companies. All these have, over time, significantly enlarged the number of interested and involved participants, with corresponding increases in their activities and outcomes. If an institution is deliberately trying quickly to become more entrepreneurial, the MIT approach would take an amazing degree of patience and self-restraint.

Outreach to alumni is achieved easily in the form of self-organized seminars, and faculty visits and
Conclusions

Educational programs require investment in and acquisition of faculty to develop and teach such programs. Effective and well-trained academics are, unfortunately, still scarce in most entrepreneurship-related disciplines. Fortunately, successful practitioners are available everywhere and the MIT history indicates that they are quite willing and enthusiastic about sharing their time and experiences with novice and would-be entrepreneurs. The list of MIT student clubs suggests the numerous ways by which students across the university might find their own paths toward entrepreneurial efforts. The $100K Business Plan Competition is the most vibrant and perhaps most effective of these clubs on the MIT campus, leading directly to high levels of new companies being formed. Students at other universities can learn easily how to undertake their own comparable competitions through attending the annual MIT $100K Global Business Plan Workshop. Furthermore, the MIT one-week intensive Entrepreneurial Development Program, conducted annually in January by the MIT E-Center, may well be a helpful supplement for those institutions attempting to create an overall program of education and student activities that will encourage entrepreneurship.

The alumni activities and educational and student endeavors provide a strong basis for building an entrepreneurial ecosystem. But formal institutional activities also are critical. At MIT, changing the Technology Licensing Office into a proactive and supportive-of-entrepreneurship program office has contributed much to technology transfer from the research labs. This was done twenty years ago and has had the time to mature in its effectiveness. More recently, MIT’s creation of the Venture Mentoring Service, its own form of volunteer lightweight but quite effective “incubation,” has generated a model of helping that is clearly possible in many other university communities. And direct, targeted funding of faculty research that has commercial potential, as done in the new MIT Deshpande Center, is certainly a possibility elsewhere.

This report has documented how much dramatic economic impact has been generated by MIT alumni, students, staff, and faculty who have formed new enterprises over the past fifty years. Throughout we have attempted to communicate the many elements of what we call this university’s entrepreneurial ecosystem and how each part has contributed to the venture formation process. In many examples we have cited, multiple aspects of that ecosystem have been at work in making entrepreneurship happen and be successful. We have tried also to show how other universities may be able to strengthen their own entrepreneurial achievements and, in turn, their contributions of economic impact to their communities, regions, and countries.
Company Database

In 2003, MIT initiated a rigorous and comprehensive survey effort, in which the authors participated, to identify, carefully study, and assess the impact of new enterprises created by all living MIT alumni. The survey produced detailed information on 4,611 companies founded by 2,111 graduates. To provide still more information about these companies, including current sales, employment, industry category, and location, this new MIT database on alumni companies was further updated and upgraded from the 2006 records of Compustat (for public companies) and Dun & Bradstreet (private companies). Our report’s findings with respect to total employment and sales, MIT-enrolled department of company founders, industry, and age of the companies, are based on this updated database. We use data only on MIT alumni companies that still were active in 2003, that information coming from a carefully conducted survey process. In this way and many others, the numbers in our report are conservative in their estimation of the total economic impact of MIT-related entrepreneurs, ignoring the entrepreneurial outcomes of the many non-alumni faculty, staff, and other employees, as well as other spillovers from MIT.

Alumni Survey

MIT conducts periodic surveys of all alumni to get up-to-date demographic information. As we indicated previously in this report, in 2001 MIT sent a survey to all 105,928 living alumni with addresses on record. MIT received 43,668 responses from alumni; of these, 34,846 answered the question about whether or not they had been entrepreneurs. A total of 8,179 individuals (23.5 percent of the respondents) indicated that they had founded at least one company. In 2003, we developed and sent a survey instrument focusing on the formation and operation of their firms to the 8,044 entrepreneur respondents for whom we had complete addresses. Of the 2,111 founders who completed surveys, approximately 2.2 percent of the cases had been reported by more than one MIT co-founder. Removing those duplicates (the average number of MIT co-founders per team is 1.29) left 2,059 unique alumni entrepreneur respondents who founded 4,611 companies. Most teams also had non-MIT co-founders, but this fact does not require any correction in the sample.

Because many of the founders of the largest MIT alumni companies no longer are affiliated with their companies or have passed away, the companies...
represented in the survey responses are somewhat more recent and average fewer employees than the universe of MIT alumni-founded companies. All told, these 4,611 specific surveyed firms included in the direct responses employ more than 585,000 people. We estimate, however, that the entire population of MIT alumni firms employs more than 3.3 million people.

The report’s findings on where and why companies locate where they do, what gives them their competitive edge, how they received initial funding, where they sell their products, and how many patents they have, are taken directly from the responses to this 2003 survey, updated to reflect the 2006 corporate information obtained from Compustat and Dun & Bradstreet. To estimate accurately the entrepreneurial activity and economic impact of those in the entire MIT alumni population who did not respond to the surveys, we multiply the direct response numbers by a scale factor. For further details, see the Appendix section, “Estimation Methods,” below.

The detailed questionnaire used for this survey is available at www.kauffman.org/MITstudy. We encourage other universities to undertake and share comparative analyses. We also should note here that, although we correctly identify all of the alumni in the MIT database as “MIT alumni,” a substantial fraction of them are also alumni of other universities in the United States and other countries. So the economic impacts cited in this report reflect the direct and indirect educational impact of many institutions of higher learning in science, technology, and management.

Estimation Methods

As in all surveys, a large segment of the alumni population did not respond to the MIT alumni surveys. Therefore, estimation of the total impact of MIT alumni entrepreneurs requires extrapolation to account for non-respondents. To estimate the numbers for the entire MIT alumni population, we multiply by a scale factor to give an accurate estimate of the entrepreneurial activity of those who did not respond to the surveys. Since we have aggregated data from both the 2001 and 2003 MIT surveys, with adjustments from the 2006 Compustat and Dun & Bradstreet databases, the appropriate scale factor depends on the particular statistic or question being answered.

1. For survey items where we have data on all companies created over the life of the entrepreneur, the base scale factor is approximately 9.476 (i.e., 2.425 * 3.906 = ~9.476). These numbers are approximate because we actually use more than three digits after the decimal. We multiply by 2.425 because, as indicated above, the total population of MIT alumni is 105,928 and 43,668 responded to the first survey. To get from 43,668 to 105,928 we have to multiply by 2.425 (i.e., 105,928/43,668 = ~2.425). Then we multiply by 3.906 because 8,044 indicated that they were entrepreneurs and only 2,059 responded to the Founder’s Survey (i.e., 8,044/2,059 = ~3.906). We multiply that by 0.773 to avoid duplicate counting by correcting for multiple MIT alumni on the same founding teams. Because 23.4 percent of the reported companies were out of business by 2003, we finally multiply by 0.766 to count just those companies likely to still be active.

2. For items where we only have data on one of the companies the entrepreneur founded, we then multiply by 1.61 because 1.61 is the number of companies on average each entrepreneur has founded (27 percent of the entrepreneurial alumni are repeat/serial entrepreneurs). For example, if we take 100 alumni entrepreneurs, on average they would have created 161 companies during their careers. If we only have data on total employees for one company each (100 companies), then we must multiply by 1.61 to get an estimate of the real total number of employees for all the companies founded by that entrepreneur.

3. We further adjust the scaling factor for items where data are missing due to entrepreneurs skipping a survey item. This process may seem
complicated, but it gives a much more accurate estimate than any previous efforts.\(^9\)

It is important to point out that, although we correctly identify many MIT alumni-founded companies in various discussions throughout this report (e.g., Tables 10 and 11), in the underlying database that gets scaled we only use those firms formed by alumni who completed survey reports in 2003. Thus, some very significant MIT alumni firms were NOT included in the database, such as Arthur D. Little, AMP, Campbell Soup, Genentech, Hewlett-Packard, Intel, McDonnell Douglas, Raytheon, Rockwell, and Texas Instruments, because the MIT founder had died in all these cases. These omissions illustrate the importance of the scale factor we employed to produce a more accurate estimate that partially compensates for the many firms explicitly omitted.

This scaling method rests on three assumptions. One is that the proportion of entrepreneurs among the respondents is the same as the proportion of entrepreneurs among the non-respondents. The second is that the respondent entrepreneurs are equally as successful as the non-respondent entrepreneurs. The proportion of entrepreneurs among the non-respondents (or their success level) could just as easily be higher as it could be lower than the proportion among the respondents. The third is that, for entrepreneurs who started more than one company, then on average the performance of their former or subsequent firms is similar to the firm we observe.

Let’s consider how wrong we might be in these estimates. The effect of cutting our scale factor by two (which would represent the extreme case where twice as many respondents as non-respondents were entrepreneurs, or where respondent entrepreneurs were twice as successful as non-respondents), generates the results that are in the conservative wording we chose to use in the introduction of this report:

...if the active companies founded by MIT graduates formed an independent nation, conservative estimates indicate that their revenues would make that nation at least the seventeenth-largest economy in the world.

Under these circumstances, we would be estimating that 12,900 companies created by MIT alumni employ 1.6 million people and have annual world sales of $1 trillion. That is roughly equal to a gross domestic product of $500 billion, a little less than the GDP of the Netherlands and more than the GDP of Turkey (2006 International Monetary Fund, nominal GDP—not purchasing power parity or PPP).

\(^9\) Similar extrapolation methods were used in a recent study of immigrant entrepreneurs’ role, using a scale factor to extrapolate from 2,054 responses in their survey database to the estimated economic impact drawn from 28,776 companies, a scale-up factor of ~14.010 (Wadhwa et al., 2007).
References


Chase Manhattan Corporation. MIT Entrepreneurship in Silicon Valley (Privately published, April 1990).


People and Excellence: The Heart of Successful Commercialization

People and Excellence: 
The Heart of Successful Commercialization

talent research capital

The Minister of Industry appointed us to the non-partisan Expert Panel on Commercialization in May 2005. We were asked to identify how the Government of Canada could help ensure continuous improvement in Canada’s commercialization performance.

Specifically, our task was to examine how to transform knowledge and technologies (whether developed in Canada or abroad) into new products, services and processes in response to market opportunities; how to ensure that new knowledge and technologies generated using public funds will lead to practical applications; and whether Canada has created the right business environment for commercialization.

Our various backgrounds and expertise in the private, public and academic sectors provided the opportunity to develop a cohesive, practical road map. We acted as individuals on the panel, not as representatives of our organizations, industries or communities.

We approached the task in a number of ways. We reviewed the evidence-based research available to help us in our deliberations, and sought the advice of those in the business, academic and public policy arenas. Eight experts from across the country and abroad then reviewed the report. We discussed these findings and recommendations among ourselves, and applied our own knowledge and experience to what became robust, lively debates.

Our discussions led us to focus on three areas — talent, research and capital. The recommendations we are submitting come with our unanimous approval, and reflect our principles and values and the criteria we used to assess new programs, as set out in Appendices B and C. The recommendations in this report are submitted recognizing that we are in a fierce global race, and that our commercialization system must be integrated and consistent, yet flexible and adaptable.

The report calls for a systemic approach and immediate action. Its underlying premise is that successful commercialization occurs when the supply of high-quality ideas and research is met by a demand from competitive businesses for innovation. People and excellence connect ideas to the marketplace.

We would like to thank Industry Canada for the services of the Expert Panel on Commercialization Secretariat, and would like to thank the Secretariat itself for its tremendous help in preparing this report. We deeply appreciate the contributions of the people who provided input, especially those who reviewed drafts of this report. We are grateful for the opportunity to make this contribution. It has been a privilege.

Joseph L. Rotman, Chair

Panel Members

Germaine Gibara
Mike Lazaridis
Cindy Lum
John C. Risley
Indira V. Samarasekera
By any standard, Canada’s economy is performing well. We are enjoying a period of growth not seen since World War II. Unemployment rates are at record lows, and our ratio of debt to gross domestic product (GDP) is steadily declining. But the past is not prologue, and we face significant challenges. Emerging economies such as China and India are industrializing at a rapid pace, creating exciting market opportunities but also putting strong pressure on our traditional manufacturers. Other countries are responding to these new realities by adding value through investments in innovation.

In such a world, Canada’s weak productivity — particularly in relation to our largest trading partner, the United States — argues forcefully for a renewed commitment to bolstering commercialization.

Today, Canada has a unique opportunity — to build, from our current economic strength, an enduring national advantage, and to excel in expanding the critical capacity to translate the ideas in our heads into products, processes and services in the market. The latter is the key to success in a world where competition is global, change is rapid, and knowledge is a critical source of competitive advantage. But, first, we must act.
A New Model of Leadership – The Commercialization Partnership Board

Successful commercialization is market-driven, but, at the moment, there is a fundamental disconnect between the people who make commercialization happen and government efforts to encourage it. More must be done to ensure that the private sector has a strong voice in the design of public policies to improve commercialization in Canada.

The creation of a business-led Commercialization Partnership Board (CPB) would help change this dynamic. The CPB would be the lead advisory body to the Minister of Industry on commercialization issues. It would provide guidance on changes to existing government programs, the creation of new programs and the assessment of results. It would also commission policy-oriented research on key long-term challenges, including business framework issues such as taxation, regulation, intellectual property and competition.

The Government of Canada should act on the insights and expertise of the Board, which would provide advice on how to continually improve the policies and programs that support Canada’s commercialization performance. Specifically, the CPB would:

- submit an annual report to the Minister of Industry, who would respond on behalf of the government; and
- identify strategic opportunities for Canada to build on its competitive advantages and exploit emerging opportunities.

Supply and Demand

There are two sides to successful commercialization — the supply of ideas and people, and the demand from the marketplace for new products and processes.

Canada has come a long way in addressing the supply side of the commercialization equation. It has increased funding for university research that produces both the knowledge and the talented people needed for commercialization, and it has employed tax measures to attract risk capital.

But there is a broad range of evidence that Canada is still struggling on the demand side — in the pull from the private sector. For example, Canadian businesses employ fewer researchers and university-educated business managers, perform less research, and win fewer and smaller risk capital deals than do their U.S. counterparts. The panel believes that while Canada needs to expand and renew its supply-side measures, it must now focus its efforts on the demand side, reducing the barriers and perceived risks that make businesses reluctant to engage in commercialization.
Three Themes for Action

Successful commercialization has many elements: critical management skills, vision and a highly qualified workforce are vital; scientific and technological discovery are important for all sectors of the economy; and access to capital at each stage of a company’s life is essential.

To kick-start the process that would be sustained through the CPB, the panel has identified three specific areas that require early action by the federal government. These three areas — talent, research and capital — all share a common focus on people and excellence:

• People turn great ideas into new products and services, making the strategic business choices that result in commercial success.

• People engage in research, generating ideas that have commercial potential.

• People use capital to move through the many stages leading to successful commercialization.

Focusing on people and excellence in these three areas will make a difference for Canada in the global race to compete.

TALENT

Since it is people who develop ideas and move them to the marketplace, Canada needs to increase the presence of highly qualified workers and managers in Canadian businesses. Our recommendations on talent also reflect the need to raise the demand for highly qualified workers in business, while continuing to promote excellence in the skills needed for commercialization. Measures in these areas will also strengthen the demand for innovation and commercialization. We see particular benefit in programs that place skilled students and recent graduates in business settings. Such programs not only improve the ability of companies to commercialize, but help refine the skills that graduates need to make smooth transitions to the business sector.

To foster a supply of talented workers, we must maintain strong support for Canada’s post-secondary education system, undertake greater efforts to attract more of the world’s leading minds to this country, create employment opportunities, and encourage Canadians to gain exposure to other cultures and markets. Finally, Canada must bring about a long-term change in its culture to ensure business and technical achievement are valued more highly. To achieve this, attention should be focused on Canada’s youth. We recommend initiatives that will:

• increase business demand for talent, through the development of a new Canada Commercialization Fellowships Program;

• spur private sector hiring of highly qualified personnel with commercialization talents;

• encourage and celebrate young Canadians who aim for success in science, technology and business; and

• develop and retain talent for success in the global marketplace.
RESEARCH

There is substantial research activity in Canada, but too little takes place within the private sector. The challenge for government is to increase — not merely maintain — its investments in publicly funded research, while encouraging private sector research and development (R&D). Business leaders, in collaboration with publicly funded research institutions, can identify areas for research and skills development that will position Canada for global leadership.

Small and medium-sized enterprises (SMEs) are pivotal players in business supply chains. With further support, they can build the bases needed to attract additional capital and employ more talent. In particular, seed and start-up firms can benefit from government support at the earliest and most risky stages of product and service development to help them overcome gaps in the financing marketplace. Experience from other countries points to approaches that can address government needs while encouraging research by SMEs.

We recommend initiatives that will:

• create a Commercialization Superfund to address key commercialization challenges;

• expand federal programs that support seed and start-up firms in proving their business ideas; and

• increase the commercialization involvement of SMEs, through a Canadian SME Partnerships Initiative.

CAPITAL

Finally, Canada must ensure that its capital markets are working effectively, getting funding and management expertise to promising commercial opportunities. One immediate goal should be to stimulate increased investment by angel investors, who provide firms with both financial capital and, in some cases, the benefit of their experience, contacts and mentorship.

The panel also proposes a series of tax measures to promote greater influxes of foreign capital and expertise. We also believe an in-depth analysis of how Canada can improve the climate for venture capital investment is also required, with the objective of strengthening the investor community and improving the quality of business opportunities.

We recommend initiatives to:

• improve access to early-stage angel financing and expertise;

• review and identify improvements in Canada’s expansion-stage venture capital market; and

• remove barriers to investment for foreign venture capital investors.

Summing Up

Many others have reached the same conclusions and proposed similar recommendations as this Expert Panel on Commercialization. The key is execution. In this respect, our report and its recommendations are only a start. The panel believes that two key steps are required to position Canada as a recognized leader in the global marketplace:

• creating, through the CPB, stronger relationships among the business sector, the federal government and other key institutions such as universities; and

• acting immediately in the specific areas where needs exist, with these actions monitored by the CPB to ensure concrete results and enable further decisions.

Creating the CPB is a crucial first step in these processes.
Understanding Commercialization

Commercialization includes everything a firm does that transforms knowledge and technology into new goods, processes or services to satisfy market demands. Commercialization is applicable across all economic sectors and is as relevant to Canada’s natural resource industries, manufacturers and service providers as it is to its advanced technology companies.

Commercialization is anchored in the world of business and is affected by many factors, including:

- the pull of the marketplace;
- the flow of ideas through research efforts within the firm and from outside it;
- financial, operational and human resource strengths;
- the quality of the market information available for decision making; and
- whether the corporate culture values innovation and a focus on customers, and accepts that trial and error, risk, and failure are normal bumps on the path to success.

Section I
Defining Canada’s Commercialization Challenges

The broader culture within which businesses operate also influences commercialization through a number of elements, including:

- the public sector’s framework of laws, policies, programs and supports, including those related to intellectual property, regulation and tax regimes;
- the degree to which competitive forces drive innovation throughout the economy;
- the role of publicly funded research and education in generating knowledge, and the roles of skilled people who know how to create, build on and apply this knowledge;
- the encouragement of alliances, networks and other forms of connections among businesses, governments, educational institutions and other partners; and
- whether society in general views personal achievement and business success as positive values.

Two elements are at the heart of commercialization — people and excellence. People identify market opportunities, carry out research, train others, make investment choices, build networks and create successful businesses. People, therefore, are the ultimate competitive advantage.

Excellence determines who wins in the face of emerging market opportunities, and can be seen in commitment to a talented, highly trained workforce; world-class research; and far-sighted investment.
The Case for Action

Why is it so essential to foster commercialization in our economy?

Despite the fact that Canada's economy is performing well, there are significant challenges on the horizon. First, today's economy demands that organizations in all sectors create value by adding knowledge. Second, our workforce is aging, threatening our ability to sustain strong economic growth unless workers are given the tools to add more value. Finally, Canadian businesses are facing increased competition from nations such as China and India, which are just beginning to realize their industrial potential.

Improving Canada's productivity growth will be crucial to meeting these challenges. Unfortunately, Canada does not have a strong recent track record in this area. Productivity growth in the Canadian business sector averaged only 0.7 percent per year from 2000 to 2005, a sharp slowdown compared with previous years, and a much poorer record than that of the U.S., our major trading partner.

An important element of Canada's productivity challenge is its inability to capitalize on innovation and discover new and better ways to add value to what it sells. The key to solving this is in commercializing knowledge — the surest path to enhancing productivity and sustaining economic prosperity. Enhancing productivity will also help to close the prosperity gap that has opened between Canada and the U.S. — a gap that now accounts for a difference of about US$8200 in average annual income between Canadians and Americans.¹

Commercialization in Canada: How Are We Doing?

Commercialization does not lend itself easily to measurement, but a number of indicators suggest that Canada lags behind its major international competitors. European firms tend to derive a higher proportion of total sales from recent innovations than their Canadian competitors. Sales from new or improved products accounted for 35 percent of all sales by Canadian firms having Canada-first or world-first innovations. This figure is 54 percent in Germany.² Data for the U.S. is not available.

Ontario’s Institute for Competitiveness and Prosperity found that Canadian firms lag well behind their U.S. counterparts in terms of patents granted per 10,000 employees, an important indirect measure of commercialization, even when firms in the same business sector are compared.³ The use of information and communications technologies used to embed knowledge in services and products has risen in Canada, but at a slower pace than in countries such as the U.S. and Finland.

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³ Roger L. Martin, Realizing Canada’s Prosperity Potential (Toronto: Institute for Competitiveness and Prosperity, 2005).
This economic evidence of lagging Canadian commercialization is backed up by survey data showing that Canadian businesses prefer strategies based on cost containment rather than innovation. In 2001, fewer than 40 percent of businesses in Canada considered developing new products or production techniques as important to their business strategy. More than half, however, believed that reducing labour and other operating costs was important. The most recent Global Competitiveness Report ranked Canadian businesses 27th overall in their propensity to compete on the basis of unique products or processes rather than low-cost labour or raw materials.\

These findings suggest that changing Canada’s prevailing business culture will be the country’s main commercialization challenge. Corporate strategies must shift toward competing on the basis of excellence and innovation — including new, higher-value products, services and processes — through better commercialization of ideas across all sectors of Canada’s economy. Implementing such a strategy will require firms to increase their capacities in talent, research and capital.

Our review of the evidence indicates that Canada has in place many of the investments needed to support innovation: public funding for R&D, a solid infrastructure of colleges and universities, and a business environment conducive to innovation. Canada’s real opportunity for improvement is in increasing business demand in order to achieve a greater return on these investments.

**DRAWING ON THE PANEL’S EXPERIENCE, EXPERTISE AND BEST JUDGMENT**

The panel members have substantial experience as leaders of organizations in the private and academic sectors. We, therefore, not only assessed the evidence but also drew on our collective experience and applied our own judgment.

We vigorously debated what was practical and achievable. From these debates we developed a shared view on many issues, most importantly, striking the right balance between supply measures — those that improve the supply of talent, commercialization-directed research and capital — and demand measures that will encourage Canadian businesses to commercialize.

It is necessary to make informed choices about Canadian business framework policies such as taxation, regulation, competition and intellectual property protection. We are well aware of, and sympathetic with, recommendations in these areas from individuals and groups whose counsel we respect. However, given that the federal government has reviewed many of these issues in other forums, and that we have limited time and resources, we saw little value in duplicating this other work. Further, our expertise and knowledge lay elsewhere.

Finally, we recognize that the relationship between successful commercialization and many broad framework policies is not always clear. Section IV of this report sets out our views on the need to analyze these business framework issues in detail.

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5. For example, the federal government has received recommendations from the External Advisory Committee on Smart Regulation.
6. For example, the National Science Advisor has noted that there is no strong relationship between corporate tax rates and private sector R&D efforts. Countries that have low corporate taxes (e.g. Sweden and Finland) tend to be leaders in business R&D, but countries that have higher rates are not far behind (e.g. Japan, the U.S. and Germany).
From our review of the evidence and our own experience, we identified three core elements of the commercialization system in Canada in which change could have the biggest impact:

**Talent** – by ensuring that Canada creates, attracts, retains and employs the full range of talents needed for sustained commercialization and fosters a culture of internationally competitive excellence in all fields.

**Research** – by building on the existing Canadian bases of R&D in traditional science and technology disciplines and in fields such as design, market research and business management.

**Capital** – by increasing the capacity of smaller and younger firms and entrepreneurs to gain access to the capital needed at different stages of the commercialization process.

Within each of these elements, we combined the available evidence with our own experience to assess the situation facing Canada and develop recommendations. The result is a set of recommendations that form a comprehensive, practical and achievable package. We structured many of these recommendations so that they would begin as pilots and be scaled up or down based on new evidence, results and the best opportunities available to improve commercialization.7

We believe that the federal government’s commercialization policies do not adequately address the demand side of the commercialization equation. For example, while Canada provides generous tax incentives for business R&D, it continues to underperform in this area. The reasons for this are complex, but this underperformance indicates that the current approach is not meeting private sector needs (since they have not changed their behaviour in response to these incentives). Correcting this will require more private sector input into the design of support programs. The Government of Canada has no formal body dedicated to engaging business people on these issues. However, demand considerations must be the cornerstone for decision making. Our recommendations begin by addressing this gap.

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7. The appendices of this report (published in a separate volume) provide more detailed evidence and analysis of the issues that led the panel to its conclusions and recommendations. The recommendations have been designed so that existing institutions can take responsibility for implementing them, although other approaches have been proposed where the panel could not find an obvious choice among potential implementing organizations.
RECOMMENDATION
Create a Commercialization Partnership Board

PROPOSAL

We recommend that the Government of Canada create a Commercialization Partnership Board (CPB) reporting to the Minister of Industry as his or her lead advisory body on commercialization. Its mandate would be distinct from those of other advisory bodies. It would:

- make recommendations with respect to the major commercialization initiatives we are proposing, such as the Canada Commercialization Fellowships Program, the Commercialization Superfund, a new Angel Co-Investment Program and the Canadian SME Partnerships Initiative (described below);
- serve in an oversight role for federal commercialization policies, initiatives and investments, and provide an annual public report evaluating their effectiveness, integration and impacts;
- call on the Minister of Industry to respond publicly to the above-mentioned report;
- assess the implementation of the recommendations in this report, identify improvements, and advise on when it is appropriate to move from pilot to full-funding status for each recommendation;
- encourage linkages to, and coordination with, the many provincial/territorial government strategies and organizations working to support commercialization;
- build support in the private and public sectors for a sustained effort to improve Canada’s commercialization outcomes; and
- provide policy-focused advice to the Minister on improving commercialization in Canada, including guidance on government-business framework issues such as the competitiveness of internal markets, regulation, intellectual property protection and taxation.

To do this, the CPB must be:

- rooted in the marketplace;
- focused and strategic in its advice;
- led by a respected commercialization expert from the private sector, with members who are knowledgeable, experienced and committed to getting results for Canada;
- driven by a culture of commerce and an awareness of the most current domestic and international commercialization realities; and
- focused on the need for better evidence on commercialization in Canada.

The Minister of Industry would appoint a full-time president who would devote his or her time and resources to ensure, through personal leadership and continual interaction with the community at large, that commercialization is kept at the forefront of public and economic thinking in Canada. Other CPB members should be drawn from the business community, academia and organizations focused on commercialization-related goals bringing partners together from all sectors (commonly known as fourth-pillar organizations). These members should reflect the entire commercialization system but not be collectively or individually accountable or beholden to any other organization or mandate while exercising their responsibility. At least one member should be from outside Canada so that the CPB can draw on international best practices. Officials from key government research and commercialization organizations should be included as ex officio, non-voting members. Deputy ministers would be asked to attend when it is relevant to their departments.

The CPB would require the support of an independent, full-time secretariat, whose executive director would be selected by, and accountable to, the president of the CPB.

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8. Fourth-pillar organizations are usually independent, non-profit entities funded jointly by government and the private sector to provide a catalytic role for the other three pillars: business, government and post-secondary education institutions. For example, Precarn Incorporated was created, and is funded, by partners from these three pillars to support the development of intelligent systems technologies.
To create the CPB, an interim board would be established with a one-year mandate to do the following:

- Develop an implementation plan for the recommendations of the panel, monitor the implementation of these initiatives, develop a plan for assessing their outcomes, and provide recommendations for improving, modifying or cancelling initiatives.

- Develop terms of reference, a budget, strategic plans and timelines for the creation of the CPB and ensure a clear mandate, as outlined, for the organization. This mandate will be distinct from those of other bodies with broad advisory mandates, such as the Prime Minister’s Advisory Council on Science and Technology and the Council of Science and Technology Advisors, because it is focused strictly on commercialization. It will also differ from the proposed national advisory board of the pilot projects to commercialize university and federal laboratory research, in that the CPB will focus on private, rather than public, commercialization issues. The panel expects, however, that the CPB will work closely with the bodies mentioned in areas of common interest.

- Nurture collaboration between the private, public and other sectors, particularly in areas where Canada has, or could develop, a competitive advantage in commercialization, and where private sector commitment to commercialization can be increased.

The CPB itself should have an initial four-year mandate. After that, its effectiveness should be reviewed by an internationally recognized panel of experts on commercialization, to determine whether it should continue, be changed or be cancelled.
TALENT

Canada’s competitiveness and capacity for commercialization depend on the talent and ingenuity of people who combine knowledge and resources in new ways. Canada needs a well-educated workforce whose skills, knowledge and creativity can compete with the best in the world — and it needs to put their skills and education to work in a way that spurs innovation and benefits businesses.

In many respects, Canada is doing well in the supply of talent. Among 15-year-olds, Canadians are exceeded in their math abilities only by students in Hong Kong and Finland. Canada ranks first among Organisation for Economic Co-operation and Development (OECD) countries in terms of the share of its working-age population with post-secondary education. But this same OECD data reveals that we have proportionately fewer university graduates and — at the very high end — we are producing new PhD graduates at a much slower pace than major competitors such as the U.S.

More fundamentally, there is concern about the extent to which Canada’s universities have the capacity to significantly increase the number of graduate students. In particular, the Association of Universities and Colleges of Canada estimates that U.S. universities have 50 percent more funding per student for teaching and research.

The Government of Canada has partly addressed these problems by establishing programs such as the Canada Millennium Scholarship Foundation and the Canada Graduate Scholarships to allow more Canadians to pursue a post-secondary education. Federal funding has also been increased for the granting councils and other funding organizations, in order to support Canada’s research community. But these problems are a moving target, and Canada cannot afford to rest on its laurels.

As noted, a greater challenge for Canada’s commercialization performance is inadequate demand for talent. In general, Canadian businesses have a weak record for hiring people with the skills needed for the full range of commercialization activities. For example, Canadian managers are only half as likely as American managers to be graduates of business programs.

Among financial professionals, 18 percent in the U.S. have a master’s degree or higher, compared with only 8 percent in Canada. And, U.S., Japanese and German companies employ significantly more researchers per thousand employees than do Canadian firms.

Most tellingly, the wage premium for highly qualified personnel is lower in Canada than in competitor countries, particularly the U.S. The wages for highly skilled workers have not risen relative to the Canadian average in recent years.

Placing highly qualified personnel — from all education disciplines — in business environments will spur demand by influencing the way firms create opportunities, encourage greater involvement by firms in research, increase the flow of knowledge to businesses from academia, and broaden understanding of international markets.


RECOMMENDATION
Increase Business Demand for Talent Through Development of a New Canada Commercialization Fellowships Program

PROPOSAL
We recommend that the federal government create a new Canada Commercialization Fellowships Program. The program would support businesses in all sectors that are building or renewing a commitment to commercialization by supporting exchanges with post-secondary institutions. These fellowships would encompass the broad range of disciplines that support commercialization, such as management, marketing, market research and design, as well as the sciences, technology and engineering. These exchanges will happen throughout the career cycle:

- **Undergraduate Fellowships** will provide work experience and scholarships for Canadians entering a university in Canada. The winners of the regional and national science fairs and youth business competitions discussed later in this section should qualify automatically for these fellowships.

- **Graduate Fellowships** for master’s and PhD students in Canadian universities will give participants work experience, training and research skills in both university and business settings in order to improve their ability to bring commercialization skills to Canadian workplaces.

- **Post-Doctoral Fellowships** will include support for specific efforts in order to bring ideas to market and provide funding for training and research that are relevant to commercialization.

- **Career Interchange Fellowships** will concentrate on two areas:
  - the temporary or part-time movement of post-secondary faculty into industry, and of people from industry into academic environments, creating a cycle for fellows to move ideas between both sectors; and
  - a mentoring and exchange program for a select group of mid-career professionals and next-generation angel investors and venture capitalists, who will work in, and learn from, successful venture capital firms in Canada and around the world, enabling the fellows to apply international best practices to commercialization in Canada.

- **Chairs of Research in Practice** will focus on people that have PhD degrees and substantial experience in industry and/or academia in Canada. The funding for these chairs will support multi-year projects that include the supervision of graduate students; direction of a research team in a business, not-for-profit organization or public research institution; and management of a project that will add to commercialization knowledge and its application.

The intentions of the Canada Commercialization Fellowships will be to encourage students not inclined to business to explore this option, and to encourage firms not currently employing high-end talent to do so. These intentions must be reflected in the program’s design.

The dollar value of the fellowships must be irresistible in order to attract and retain the best and brightest from around the world. Funding decisions for all of these fellowships should be guided by how well proposals expand business demand for people with the skills needed for commercialization. After a reasonable tenure, the cost of continued employment with the firm would be borne by the company.

Program administration will involve two complementary parts. One part will assess fellowship candidates’ qualifications in much the same way that applicants for scholarships and research grants are currently evaluated. The second part will assess how well proposals will improve the commercialization-relevant skills of the candidates and the commercialization capacity and outcomes of the host and/or home organization(s). Ensuring that a delivery organization has the ability to assess both the demand and supply elements of the program will be a key challenge for the CPB in its oversight function. The CPB will need to ensure that the fellowships add to any existing initiatives so that firms can gain new perspectives on commercial opportunities through the application of knowledge.

People and Excellence: The Heart of Successful Commercialization
REASONS FOR ACTION
Canada is growing the supply of talent, and it must strengthen private sector demand for that talent. In our view, the way to do this is by reducing the initial costs. Once in place, the fellows will demonstrate their value, change the culture of their workplaces and make commercialization self-sustaining.

Funding Requirements and Expected Results
The panel estimates that funding for the Canada Commercialization Fellowships should begin at $65 million per year on a pilot basis, scaling up to $275 million per year once their effectiveness has been confirmed by a CPB-led review. This would provide funding for up to 5000 fellowships and associated research budgets in any one year. The panel expects that the fellowships will:

• increase the number of highly talented workers with commercialization-relevant experience in both academic and business settings;
• increase the capacity for, and commitment to, innovation and commercialization among Canadian companies; and
• improve the flow of knowledge from academia to business on recent scientific developments, and from business to academia on market needs.

RECOMMENDATION
Spur Employer Hiring of Recent Graduates with Commercialization Talents

PROPOSAL
We recommend that the federal government increase existing support to Canadian businesses to hire recent graduates on projects aimed at commercialization and innovation by:

• expanding the existing Canadian Institutes of Health Research (CIHR) programs that focus on industry–university partnerships;
• expanding the existing Natural Sciences and Engineering Research Council of Canada (NSERC) programs that provide research experience in industrial settings;
• creating a new Social Sciences and Humanities Research Council of Canada (SSHRC) commercialization and innovation fellowship program emphasizing disciplines such as business, design and human behaviour; and
• providing funds to these organizations based on a competition overseen by the CPB.

The federal government should support this recommendation by increasing funding for the granting councils involved, not by reducing funding for existing programs. What’s more, this new money must be complemented by more aggressive campaigns aimed at Canadian employers to demonstrate the benefits of drawing on Canada’s highly qualified graduates to spark innovation and commercialization.

REASONS FOR ACTION
The two organizations at the centre of this recommendation, NSERC and the CIHR, are already demonstrating their value in driving Canadian commercialization. They are improving the quality of the supply of talent and linking these people to demand opportunities. For example, the number of university–industry fellowships approved by the CIHR increased from 171 in 2000 to 324 in 2004 (in response to a near tripling in applications over this period). On average, more than 60 percent of people supported by NSERC’s program are retained by the related firm, at the firm’s expense. While the number of projects funded is not large, it shows growing interest in creating opportunities for talented people to make their mark in Canada’s business sector.
While the CIHR and NSERC programs are valuable, they cover only part of Canada’s commercialization needs. Adding a new program through SSHRC would incorporate other fields critical to commercialization.

We recognize that the programs of these three organizations will continue to be highly targeted and focused on opportunities for the most highly trained graduates. However, they fit with the larger need to create stronger bridges that enable highly qualified personnel to make the transition from Canada’s universities to businesses and other applied settings.

### RECOMMENDATION

**Encourage and Celebrate Young Canadians Who Aim for Success in Business, Science and Technology**

**PROPOSAL**

We recommend that the federal government provide substantial, guaranteed and long-term support for initiatives that promote and celebrate excellence in science, technology and business by young people. This will mean much more than incremental funding for science fairs, student business competitions and similar activities across the country. It must involve:

- granting Canada Commercialization Undergraduate Fellowships and other awards to high school students who win major academic and business skills competitions;
- creating the Prime Minister’s Awards for Science, Technology and Entrepreneurship for Canada’s Youth to send a powerful message to young people and their communities;
- launching an annual, national event involving the Prime Minister to honour the young achievers who will help to build our commercialization future;
- initiating new awards to honour leading-edge innovation by young people in new or non-traditional fields that encourage intellectual and commercial risk taking; and
- establishing new awards to celebrate the success of young people commercializing new products, services and processes.

We recommend that a competitive process be developed to provide sustained, long-term funding to local and national organizations that can demonstrate the ability to meet the goals of this recommendation.

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### Funding Requirements and Expected Results

The panel estimates that funding for the three programs mentioned should increase by $15 million per year, initially, scaling up to an additional $40 million per year following a CPB-led review of their effectiveness. This would roughly double the amount of funding now provided to these organizations for this purpose. The panel expects that this recommendation will:

- increase private sector demand for commercialization talent through higher overall employment and an increased number of hiring companies;
- lead to reduced emigration of highly skilled Canadians in fields that are the focus of fellowships, while enhancing the recruitment of Canadian students who have studied abroad; and
- improve the flow of knowledge crucial to commercialization from academia to Canadian businesses through increased hiring of recent graduates by industry.
**REASONS FOR ACTION**

If Canada is going to foster a culture that promotes intellectual achievement and business success, it must begin with its young people.

From our experience, interest in and an aptitude for science or business develop early in life. Activities for school-aged children that fuel curiosity and develop creativity build on that early childhood base — activities as pivotal in a student’s life as winning the school science fair. The panel’s recommendations, and other government actions, will encourage young people — including young women and members of other under-represented groups — to pursue careers in science, technology and business.

Of high school students attending Canada-Wide Science Fairs in 1995 and 1996, 57 percent expressed an interest in pursuing science-related careers, compared with only about 37 percent among those who did not attend. These fairs are where children can learn scientific and business skills and put them to work. Federal leadership will provide a great incentive for Canadian companies to expand their commitment to these activities and help foster a culture of excellence in Canada’s classrooms and labs. Canada should prize excellence in these areas the same way it prizes excellence on the ice.

**Funding Requirements and Expected Results**

Funding requirements for this initiative are estimated to begin at $15 million per year, ramping up to $60 million per year once it has been demonstrated that this amount of funding can be absorbed in an effective manner. The panel expects that this recommendation will:

- accelerate the trend toward a Canadian culture that prizes excellence in the marketplace and the classroom;
- generate higher demand for enrolment in science, technology, engineering and business education programs; and
- induce more high-achieving students to stay in Canada to pursue their undergraduate degrees.

**RECOMMENDATION**

**Develop and Retain Talent for Success in a Global Marketplace**

**PROPOSAL**

We recommend that the federal government take action to attract skilled and talented individuals to Canada to support commercialization and to link Canadian students, businesses and researchers to global activity that is expanding knowledge.

**Create a Talent and Research Fund for International Study**

This fund will:

- create a set of Maple Leaf Graduate Scholarships to compete with the prestige of the Fulbright and Rhodes scholarships and attract more of the world’s finest minds to this country’s campuses;
- bring foreign research and teaching collaborators to Canada to serve as distinguished visiting chairs in disciplines that are strategic priorities for Canada and support its commercialization goals;
- provide matching grants for collaborative research projects with researchers in centres of excellence in other countries;
- support short-term exchanges of researchers between Canadian and foreign universities; and
- significantly increase the number of Canadian students conducting studies and research at foreign universities, thereby gaining exposure to other cultures and markets.

This fund should be administered by the Government of Canada’s granting councils.
Encourage International Students to Stay in Canada

Like other countries, Canada should change its immigration policies to make it easier for international students, particularly those in advanced studies, to work while they are studying here and to remain in Canada after graduation. We are pleased to see that pilot projects to address this need have been announced, and look forward to their full availability across Canada. That said, we feel that more aggressive action is required to ensure that international students with advanced degrees from Canadian universities can stay and work in Canada.

REASONS FOR ACTION

As groups such as the Prime Minister’s Advisory Council on Science and Technology have noted, Canada has to be open to international opportunities for knowledge creation, sharing and application. This is important across all disciplines relevant to commercialization, including those business-related fields critical to improved corporate management, stronger customer focus and support for innovation.

While we want to see Canada generate more knowledge to enhance commercialization results, Canadians also need to be alert to the knowledge being generated elsewhere. Indeed, some 96 percent of all new ideas and innovations are developed outside of Canada’s borders.15 Canada needs to welcome international partnerships — and the people who make them possible — as a key enabler in reaching its commercialization goals.

The panel believes that addressing the demographic challenges of a declining birth rate is necessary, in part by making Canada a more attractive place for immigrants. We support the government’s commitment to bringing down the barriers that prevent skilled immigrants from using their talents fully. However, our commercialization goals for Canada would also benefit from a commitment to an even more open exchange of talent between Canada and other countries.

As part of this, Canada has to make it a priority to attract leading intellectual talent in all relevant areas from around the world. There must be a commitment to opening Canadians’ eyes through international study opportunities, and to bringing this global perspective and experience to bear when these Canadians return to Canada. Canada should build on a solid foundation of exchanges and foreign student enrolment in implementing this strategy.

Funding Requirements and Expected Results

Initial funding requirements for this initiative are estimated to be $50 million per year. Pending review by the CPB, this amount could be increased to an estimated $190 million per year, which would provide enough funding to support 500 foreign research and teaching collaborators, 2000 short-term scholarships for Canadian students to study abroad, and more than 2500 scholarships for foreign students to study in Canada. The panel expects that this recommendation will:

- attract greater numbers of outstanding students and scholars to Canadian post-secondary institutions;
- develop more networks of individuals, both in Canada and internationally, who have gained experience through collaborations and exchanges; and
- encourage more international students to stay in Canada after graduation in order to meet demand in fields directly supporting commercialization.

15. This figure is based on Canada’s share in the world’s scientific publications, using Thomson Scientific’s National Science Indicators database, 2005.
RESEARCH

Research, whether in the private, public or academic sectors, centres on people investigating questions, experimenting to find solutions and thinking about how to match ideas to opportunities.

The panel strongly supports investments in all forms of research. From a commercialization perspective, the biggest impact of publicly funded research lies in its role in developing talented workers who then apply their knowledge in business settings. This research can also generate ideas that have commercial potential. Indeed, breakthroughs by academic researchers can lead to the creation of whole new industries. For example, Watson and Crick’s discovery of the structure of DNA gave birth to the biotechnology industry.

As noted, Canada is making progress on the supply side, particularly through increased support for research at Canadian universities. In fact, OECD data shows that Canada ranks first overall in the G7 in terms of the share of research performed in the academic sector. Most indicators — patenting, licensing income and spinoff companies — also point to improved commercialization outcomes from university research.16

Budget 2004 provided funding to develop pilot programs aimed at improving commercialization in university and government labs.17

One of the major challenges for commercialization in Canada is its relatively low level of business investment in R&D. This lack of demand has been demonstrated in a number of ways, but most importantly in business sector R&D intensity (spending relative to output), in which Canada ranks 15th among OECD countries. Moreover, Canada’s R&D-to-GDP ratio is 45 percent below that of the U.S. and 33 percent below the OECD average. Canadian research intensity in sectors commonly seen as high-technology (e.g. computing and telecommunications equipment, pharmaceuticals, etc.) compares favourably with that in the U.S., but these industries account for a smaller share of total economic activity in Canada. Low R&D intensity in other major sectors — including wholesale and retail trade, as well as motor vehicle manufacturing — has a significant impact on Canada’s relative standing.

These overall weaknesses have particularly important consequences for the Canadian economy. The OECD estimates that a one-percentage-point rise in private sector R&D intensity could increase per-capita income by as much as 12 percent in the long run.18

We recognize there are many potential explanations for the relatively weak state of Canadian private sector investment in R&D, including a lack of competitive pressures, the effects of Canada’s tax system on corporate decisions, and the effects of the country’s regulatory and intellectual property regimes. We also note that economists cannot fully explain why Canadian businesses do not invest heavily in R&D, despite the generosity of Canada’s R&D tax credit.19

The panel believes that federal support for key research challenges, matched by private sector funding, would boost private sector R&D activity. This approach would build on Canada’s R&D strength in universities, while ensuring that supported R&D is driven by demand considerations. Canada would also draw on the successful experience of other countries in encouraging commercialization in SMEs, while addressing the R&D needs of government. On the supply side, targeted increases in funding for Canadian universities and government labs would promote stronger development of ideas within these settings.

Added investments in research outside of universities must be complemented by continued increases in the public funding of research in Canada’s universities and other academic and government research settings.20


17. A collaborative approach was taken to design, and a program proposal has since been developed.


19. More comments on this are available in Section IV as issues for priority attention in the future, and in Appendix E – Historical Context for Innovation and Commercialization in Canada.

RECOMMENDATION
Create a Commercialization Superfund to Address Key Commercialization Challenges

PROPOSAL
We recommend that the federal government create a Commercialization Superfund to create commercialization opportunities in industries where Canada has potential competitive advantages. It will do this by:

• supporting large-scale private–public sector research and training partnerships; and

• expanding existing programs, and initiating new ones, to train highly qualified personnel.

The Superfund will:

• focus on fields where Canada is a market leader or can become one;

• address knowledge and/or skill gaps that have been identified by a sector or cluster of firms as critical to meeting future commercialization opportunities;

• attract commitments of private sector funding and engage multiple firms to ensure that skills development and research meet broad industry needs and opportunities;

• locate funded research and training in non-proprietary laboratories (e.g. in federal or provincial/territorial research facilities, universities or facilities jointly operated by different firms in an industry sector or cluster); and

• require collaboration among organizations in several sectors of the economy, including, for example:
  - private or public sector organizations;
  - participants in a supply chain; or
  - organizations in Canada and abroad.

During competitions for this funding, two criteria should be assessed: long-term commercial potential, and the scientific merit and feasibility of the proposals. Assessment of the long-term commercial potential of proposals should be conducted by a private-sector-led group. Assessments of proposals’ scientific merit should be carried out by existing organizations with relevant expertise and experience (e.g. granting councils). Once the organization overseeing this assessment process has determined which projects merit funding, these proposals should be forwarded to the CPB for approval and recommendation to the Minister of Industry, who would have final authority over funding decisions.
REASONS FOR ACTION

Canada’s industrial future lies in focused efforts, not small-scale initiatives. However, where to focus has always been a critical challenge for public policy. Under the Superfund, firms and public sector research organizations would commit to medium-term, large-scale projects led by industry. Such a commitment would need to be made prior to any financing from the federal government. In this way, decisions on support would be firmly rooted in demand and be backed by a cross-section of firms and research organizations, significantly improving the chances of success.

Other countries are encouraging private–public research partnerships aimed at delivering results in the marketplace. Their programs often involve the flexibility and adaptability that the panel sees as key to a successful Commercialization Superfund. The fund should supplement existing programs and provide new support to take on emerging challenges. Funding commitments will need to span the 5 to 10 years necessary to develop new knowledge and highly qualified personnel.

Funding Requirements and Expected Results

A pilot program in this area would require funding of about $50 million per year. Pending CPB review of the program’s effectiveness and potential demand, funding could rise to $250 million per year. When matched by private sector funding, this could support between 20 and 30 projects at any one time. The panel expects that this recommendation will:

- position Canada as a leading global competitor in selected sectors and economic niches;
- increase the demand for highly skilled people and research in Superfund sectors; and
- improve Canada’s capacity to commercialize ideas developed in private sector, university and government research settings, and ensure highly qualified personnel to move them forward.

RECOMMENDATION

Expand Federal Programs that Support Seed and Start-Up Firms in Proving Their Business Ideas

PROPOSAL

We recommend that the federal government increase funding for granting council programs that support private sector research at the proof of concept or proof of principle (POP) stage of commercialization. The proposed funding must, as a first step, consist of increases to successful programs such as:

- NSERC’s Idea to Innovation program;
- the CIHR’s Proof of Principle program, which provides grants to advance discoveries and inventions toward technologies that can be commercialized;
- the National Research Council Canada’s Industrial Research Assistance Program, which supports projects at the pre-commercialization stage, including demonstration and pilot projects; and
- SSHRC, to establish a program similar to these three in order to encourage, where applicable, the commercialization of the research it funds.

Funding must grow based on additional evidence of success in terms of business outcomes and the relevant agency’s responsiveness to the needs of these emerging businesses. The CPB should advise the Minister of Industry on funding under this recommendation, which should be based on a competitive process among the granting agencies, involving a strong, peer-reviewed process.

In time, the CPB should decide whether to recommend bringing the individual POP programs together into a single approach.

21. See Appendix I — Commercialization Strategies Being Used in Other Countries.
REASONS FOR ACTION

Increased funding for research in Canadian universities has led to a growth in spinoff companies, greater licensing of innovations and other commercial benefits.23

One of the most critical points for this kind of government action is at the POP stage of commercialization. It is critical that the discoveries emerging from scientific research be brought to a stage where sources of private sector funding, such as angel investors and venture capitalists, can better appreciate their proposed value.

Existing programs provide both financial help and broader assistance to emerging entrepreneurs, thereby helping them develop their business talents. These programs are building track records by helping budding entrepreneurs make the leap to the culture and expectations of the business world. The risk capital community needs to link to these programs so that these projects can gradually progress from government support to support from the private sector at later development stages. Given evidence that start-up firms routinely succeed or fail on the strength of their business skills, Canada needs to do more at this stage.

Funding Requirements and Expected Results

The panel recommends injecting an additional $10 million per year into the programs mentioned, scaling up to $50 million per year following review by the CPB. This would lead to an approximate doubling of financial support in this area. The panel expects that this recommendation will:

• result in more successful commercialization initiatives;
• enhance investor interest in POP-supported initiatives; and
• expand awareness of business and commercialization demands among academic researchers with potential ideas for commercialization.

23. For evidence in this regard, see, for example, Association of Universities and Colleges of Canada, Momentum, or Cathy Read, Survey of Intellectual Property Commercialization.
RECOMMENDATION

Increase the Commercialization Involvement of Small and Medium-Sized Enterprises Through a Canadian SME Partnerships Initiative

PROPOSAL

We recommend that the federal government expand its existing and planned support to SMEs by creating a new Canadian SME Partnerships Initiative to help SMEs become more globally competitive. This support will come through two initiatives: research funding and program support.

Canadian SME Partnerships Initiative — Research Funding

Under this program, federal science-based departments and agencies will compete for five-year funding for research above and beyond their existing budgets. In practice, these departments and agencies will identify topics representing scientific and technical problems requiring innovative solutions (including process innovations). Departmental proposals would be assessed on how well they address public policy priorities, and their potential for future commercial applications. As in other countries with similar initiatives, these programs will often be in fields such as resource management, agriculture, the environment and sustainable development, health, transportation and public security.

Once allocations have been determined through a competitive process, departments would use the incremental funding to support R&D projects carried out by small and medium-sized private sector firms (not academic or public sector research institutions). Funding decisions on individual projects will be left to the individual departments.

Funding for the SMEs will cover two stages:

• feasibility funding, with limited funds for short-term investigation of scientific merit and feasibility; and

• prototype funding, with more extensive funds for the further development of projects with strong scientific and commercial merit (both domestic and global).

After the prototype stage, firms will look to other sources of risk capital to develop their products, services or processes for commercialization.

Canadian SME Partnerships Initiative — Program Support

There is a real need for better support for SMEs engaged in the commercialization of new or substantially improved products, services and processes. This improved support should include efforts to help SMEs reach new international customers, both directly and through international alliances. Federal departments are in the process of examining their efforts in science and technology and in emerging markets. With this work in mind, consideration should be given to significantly expanding support for SMEs through measures such as support for technology acquisition and information gathering, and R&D partnerships with firms and research bodies in other countries. The focus should be on market research and marketing information, guidance and support.

REASONS FOR ACTION

Canada’s leading-edge innovation and commercialization often start with small firms created to pursue a specific idea, technology or innovation. These firms could be our multinationals of the future.

Canadian public policy must demonstrate a commitment to helping these firms grow and thrive in the global marketplace. It must also help create linkages between domestic SMEs and larger firms, which often look to much smaller suppliers for specific innovations, thereby providing alliances. Canadian firms can win their share — and more — of these opportunities.

24. Such departments and agencies would include Agriculture and Agri-Food Canada, the Canadian Space Agency, Environment Canada, Fisheries and Oceans Canada, Health Canada, National Defence, the National Research Council Canada, Natural Resources Canada and Transport Canada.
The panel recognizes that SMEs often need different kinds of support for their R&D activities to achieve marketplace leadership than do their larger counterparts. With fewer resources to draw on, SMEs require a much broader range of assistance to help develop their business capacities, science, technology and other strengths, and in such critically specialized fields as product design. They need more dedicated access to opportunities in order to gain global knowledge and develop relationships that can lead to growth and further innovation.

To some extent, this is addressed under current programs. The new Canadian SME Partnerships Initiative we are recommending will accelerate the needed action.

The SME Partnerships’ research funding program will be similar to what already takes place in very specific areas. A good example is the research on defence-related needs that Defence Research and Development Canada funds. We were also impressed with the experience of the Small Business Innovation Research program in the U.S., which has been very successful in boosting growth and employment in participating SMEs. This success has prompted countries such as the United Kingdom and France to develop similar programs. Another such program is now under development for the European Union.

The Canadian SME Partnerships Initiative will complement other actions recommended by the panel under the Talent and Capital parts of this section. For example, support through the Canada Commercialization Fellowships could help build the talent pool in firms that have received SME Partnerships program support funds as they’ve moved forward to implement their projects. Success in the SME Partnerships program could also enhance the technical credibility of firms in the eyes of angel and venture capital investors, as it has done in the other countries where similar programs are in place.25

For the SME Partnerships’ program support funding, we expect program designs demanding the same standards of excellence that we want to see in all programming. The goal has to be working with those companies that are determined to succeed in the global marketplace and are willing to work and take risks to get there.

This focus on risk will mean that many initiatives would fail. However, the panel believes that those that succeed will contribute more than enough to the economy to yield a large net gain from this program.26

Funding Requirements and Expected Results

The panel recommends additional funding of $50 million per year for the Initiative, reflecting an increase of roughly 15 percent in the amount of R&D funding that the federal government contracts out to Canadian business. Following a review by the CPB, this funding could increase to an estimated $200 million per year. The panel expects that this recommendation would:

- encourage SMEs to engage in research with long-term commercial potential;
- develop new ideas and address gaps in early-stage funding for promising technologies;
- promote the development of products and services that could help achieve public policy priorities; and
- create stronger links between SMEs and larger businesses.

26. Ibid.
Capital follows people with great ideas and sound business skills. However, issues of supply and demand are apparent here, as elsewhere in Canada’s commercialization system. The consensus among industry experts is that there are financing challenges in two key areas: 1) the seed and start-up phase of a firm’s operation; and 2) the expansion phase.

Given that much of the investment for early-stage firms is informal (personal savings, friends, family members and angel investors), there is no definitive evidence in this area. Still, many early-stage firms claim that they face supply gaps. They see a shortage of patient capital at all phases of their development. Current angel, seed and early-stage investors are often not able to provide adequate support, especially for companies that are beginning to grow. Indeed, anecdotal evidence suggests that the Canadian angel investor market is less developed than that in the U.S. and the U.K., with fewer networks and less wealth to reinvest.27

In terms of expansion-stage financing, we are concerned by data indicating that the average venture capital investment in a U.S. company is nearly four times that invested in a Canadian company.28 This underinvestment in Canada may reflect a public policy approach that has focused too much on the quantity of venture capital rather than the quality. Canada needs a venture capital system that works harder at finding investments on which it can place bigger bets. In the panel’s view, these smaller investments hamper Canadian firms’ ability to expand their operations and compete with their better-funded U.S. competitors. As expansion-stage venture capital financings in Canada often involve syndications with foreign venture capitalists, the panel believes that efforts to promote the flow of foreign capital into Canada are necessary.

The Government of Canada is working to increase the supply of capital for early-stage businesses. For example, the Business Development Bank of Canada recently earmarked $100 million for investment in five new, independent seed and investment commercialization venture capital funds across Canada. Many provinces and territories now have initiatives to marshal venture capital for emerging companies, both directly, from provincial/territorial resources, and by building stronger connections between potential investors and potential investment opportunities.

While this will all certainly help, the key to long-term commercialization success will be in addressing the demand-side problems that investors have identified. These problems include the low returns on investments to date, and the shortage of good proposals backed by strong management teams with track records of success.

We have approached our work from a market-based perspective and believe that measures to improve the quality of demand will eventually earn greater investor activity, and, at the same time, improve capital supply.

Our recommendations on talent should help enhance management and business skills at the firm level. Beyond these, better networking and mentoring at the local level will link people leading seed and early-stage businesses with investors who can help them improve their management and open doors to other investors.

We are less certain of the appropriate role for government in expansion-stage financing. More work needs to be done to understand how government can help in ways that are effective and do not distort markets. Accordingly, we focused on three areas for immediate federal action: improving access to early-stage angel investing and expertise, reviewing expansion-stage venture capital, and removing barriers to foreign venture capital investment.


28. Data for Canada is from Thomson Macdonald, while U.S. data is from Venture Economics.
RECOMMENDATION

Improve Access to Early-Stage Angel Financing and Expertise

PROPOSAL

We recommend that the federal government support early-stage business development by significantly improving Canada’s angel investment environment.

To achieve this goal, we recommend two actions: funding excellence in building angel investor networks, and creating a new angel investor co-investment fund program. Both should be phased in, beginning with a pilot effort. The programs would earn more funding once they have proven their effectiveness.

Funding Excellence in Building Angel Investor Networks

It is necessary to ensure that start-up firms have access to the full range of business acumen necessary to attract early-stage investors.

To develop angel investor networks and enhance the managerial and financial support they provide to early-stage firms, we propose a competitive process to fund non-governmental organizations that mobilize the resources that already exist within communities. These organizations have the knowledge, experience and expertise to foster success. The goal of this initiative is to increase the number of investor-ready firms, improve the quality of the investment opportunities they present to investors, and match them with potential investors. The winning organizations will:

• mobilize people and resources within communities to work with entrepreneurs and emerging company managers to help them become more investor-ready by, for example, providing venues for companies to test their business proposals with informal groups of angel investors, in order to help the companies develop more compelling investment cases;
• match business opportunities with investors;
• strengthen networking activities within local clusters; and
• improve linkages to regional, national and international networks of expertise (i.e. technical, marketing, export and business-related expertise).

A New Angel Investor Co-Investment Fund Program

Early-stage investing is high-risk but essential to a dynamic and prosperous country. To ensure that the community of angel investors continues to grow, investment risk must be shared.

We are proposing the establishment of community-based funds, capitalized by the federal government, which will invest alongside angel investors in seed and start-up companies. Since angel investors will have their own money invested, they will have the incentive to perform all due diligence.

These funds will leverage private investments in start-up companies that are focused on growth through commercialization and will address the need for more funds. The funds will also create incentives for growth and enable angel investor expertise to reach more entrepreneurs and start-up businesses. The funding will expand the scale of angel funds.

The return of investment capital would be structured to reinforce the notion of shared risk but also to be consistent with the commitment to providing funding for early-stage support. Some companies will fail, but those that succeed should generate returns to the economy that exceed the cost of the program.

The interim CPB will need to work with its federal government partners to identify a private sector angel investor body to provide knowledgeable and objective peer review for this recommendation. The CPB should work with expert peer reviewers to identify the proposals from community organizations in both of the recommended action areas, and will recommend these to the Minister of Industry for funding.
Angel investment is about business, not philanthropy, and any advice that angel investors provide or any contributions they make — whether on corporate strategy, alliance and network-building or operational management — are meant to improve their own returns on investment, mitigate their risk and strengthen the companies they support. Their understanding of international markets and opportunities, and their ability to pave the way to later-stage funding, often makes a crucial difference in the progress of the firms in which they invest.

Angel investors are critical to the expansion of existing commercialization clusters and to helping to build local competitive advantages. In the U.S., their importance to start-ups has been demonstrated in many ways:

- Only 2 percent of Inc. magazine’s 500 fastest growing companies received formal venture capital financing at the early seed stage.29
- Three million angel investors in the U.S. invest $50 billion annually in start-ups; their investments reach 30 to 40 times as many companies as formal venture capital investments and involve three to five times more money than comes from formal venture capitalists.
- The University of California at San Diego Connect Project has emphasized angel-type networks as part of a larger strategy that has been credited with helping to create 30 000 local biotechnology jobs and 24 000 jobs in telecommunications.

Information on Canadian angel investments is very limited. Some estimate that there are roughly 50 percent more informal investors per capita in the U.S. than in Canada.30

The panel believes that Canada needs to expand the number of people who can bring their money and experience to bear so that the country’s commercialization results can be improved. This is a legitimate public policy goal, since angel investors help to shape community attitudes and awareness of the opportunities that come from being innovation- and commercialization-centred. They are a recognized strength of many of Canada’s technology clusters, which are known for their innovative businesses. They also help foster the culture of commerce discussed throughout the panel’s recommendations concerning talent and research.

Angel investor networks often connect entrepreneurs seeking capital with potential angel investors and can be vehicles for providing advice to entrepreneurs who want to do a better job of meeting investors’ expectations. The networks are also important in overcoming two key challenges facing people who could be angel investors: the lack of information about specific investment opportunities and a lack of links to potential partners.

As in all of the panel’s proposals, the use of a competitive process will be used, in this case to support angel networks that are strongly motivated to meet the needs of both potential investors and start-up companies that are ready to grow. The panel expects that any program design will draw on lessons learned through previous initiatives, such as the recent Canada Community Investment Plan pilot. We also want to see this program be subject to peer review under the auspices of the CPB.

### Funding Requirements and Expected Results

Funding requirements to support a pilot program in this area are an estimated $20 million per year. Based on a review of the program’s effectiveness, this could rise to annual funding of $40 million. The panel expects that this recommendation will lead to:

- a significant increase in the number of recognized angel networks in Canada;
- a substantial increase in Canadian angel investment;
- an increase in the number of seed and start-up companies that successfully expand their operations, due to improved business-management capacity and enhanced funding; and
- improved networking among potential partners in commercialization activities across all sectors.

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29. Based on data from the Canadian Task Force on Early Stage Funding.
RECOMMENDATION

Review the Expansion-Stage Venture Capital Market in Canada

PROPOSAL

We recommend that the federal government, possibly with provincial/territorial governments’ involvement, launch a comprehensive review of policies, programs and other factors influencing the role of the venture capital markets on companies during their expansion stage. This review would involve the venture capital community and include assessing current initiatives and capital supply and demand considerations, including factors for firms seeking financing.

REASONS FOR ACTION

The panel devoted a substantial amount of time to discussing the role of venture capital investments in commercialization opportunities at later stages of business growth but before venture capitalists exit the business. The evidence suggests the following:

- Returns from venture capital in Canada are poor.
- The sector is less mature than its U.S. equivalent (e.g. younger, smaller, with fewer specialized funds).
- Pension funds and other institutional investors have been reluctant to commit capital in view of more profitable opportunities in other fields of private equity investment.

The panel heard from people who believe that high-potential firms will inevitably attract capital, whether Canadian or foreign-sourced. Others say that the likelihood of success increases with financing and the value added from domestic venture capital. The recent Government of Ontario decision to phase out tax credits for investments in labour-sponsored venture capital corporations has focused attention on how the current policy framework affects the Canadian private equity investment environment.

Given the international nature of capital flows today, Canada should ensure that its emerging businesses have access to foreign venture capital (see the next recommendation), and there should be a strong, viable Canadian venture capital industry. The latter was clearly identified as a federal objective in the 2004 federal budget.

The lack of clear information to support explicit recommendations on how best to improve the domestic venture capital environment was a challenge for the panel. Federal and provincial/territorial governments have policies that affect the operation of late-stage capital markets. We did not see the growth from small to medium-sized companies and from medium- to large-sized companies that we wanted. Therefore, a review of the policies and their implications for risk capital markets supporting commercialization is in order.

As well, many other countries face similar questions as Canada does on how best to improve the efficiency and effectiveness of their venture capital markets. These questions include whether to increase investments by pension funds and other institutional investors. A national conference designed to bring together experts who can comment on the experiences of other countries and who can provide information to guide policy choices for stronger venture capital markets will help policy-makers. Such a conference should be preceded by regional conferences that explore the local issues facing venture capitalists and firms seeking investment.

Funding Requirements and Expected Results

The review of expansion-stage financing is expected to cost $1 million (a one-time expense). This review should identify strategies to improve the operation of capital markets and will result in a more effective deployment of available capital. Increased venture capital investment in later-stage companies should also result.
RECOMMENDATION
Remove Barriers to Foreign Venture Capital Investment

PROPOSAL
In line with the conclusions of the Canadian Task Force on Early Stage Funding, we recommend that the federal government:

• eliminate the withholding tax on capital gains made by foreign investors in the equity of private Canadian companies;

• cover limited liability corporations that are venture capital funds or private investment funds under Canada’s income tax treaties, and exclude them from withholding tax;

• extend rollover provisions to cross-border mergers, allowing companies to get access to strategic partnerships with foreign companies without triggering taxation; and

• eliminate the requirement that non-Canadian investors file a Canadian income tax return.

REASONS FOR ACTION
While the extensive review process of the previous recommendation would take some time, we believe immediate action can and must be taken to expand Canadian access to foreign venture capital. Foreign investors are increasingly present in the Canadian marketplace, seizing opportunities through syndications with Canadian venture capitalists and other investors. The growth of foreign venture capital financing is such that 27 percent of all venture capital financing in 2005 came from international sources.

To do more, Canada needs to address the barriers arising from current Canadian tax laws, regulations and policies. In this respect, we endorse the recommendations of the Canadian Task Force on Early Stage Funding aimed at improving the flow of foreign money into Canada.31 This will not only increase the availability of funds for investment but will also increase Canadian talent in venture capital analysis and management that is essential to developing Canada’s risk capital marketplace.

Moreover, Canadian companies themselves stand to benefit considerably from venture capital firms’ direct links to key suppliers and customers, and from their specialized management and marketing expertise. These benefits will promote the growth of the innovative Canadian companies that Canada needs in order to reach its commercialization goals.

We understand the belief that emerging Canadian companies will be pushed by their foreign investors to move operations to the U.S., or that the investments will lead to foreign buyouts. Our belief, however, is that if the federal government moves promptly on our recommendations, Canada will strengthen its entire commercialization system. This will reduce the attractiveness of other countries to Canada’s emerging companies. The real gains will, therefore, be far greater than any potential losses. Canada will be letting the free market work.

Expected Results
Implementation of this recommendation should:

• increase foreign investment in syndications and other funding pools supporting faster growth by Canadian early-stage companies; and

• improve the capacity for venture capital investment in Canada.

31. This task force, led by Daniel Muzyka, Dean of the University of British Columbia’s Sauder School of Business, and co-sponsored by the National Research Council Canada, delivered its report in December 2004.
To succeed in today’s world, nations must build on their strengths and embed knowledge into everything they do. Many countries are making systematic efforts in this regard by pursuing a focused, national, long-term approach to the commercialization of technology and know-how and to the large-scale investment essential to efforts to increase competitiveness. Canada must do the same.

Our 11 recommendations require Canada to focus its existing efforts, and require a commitment from the federal government to increase its investment by approximately $1.108 billion once the recommendations are fully implemented. Following is a list with each recommendation and a rough estimate of its cost to the federal government. These cost estimates are meant to illustrate the size of the program being recommended, and are not definitive. More definitive estimates will require further analysis.

### Commercialization Proposals — Financial Summary (Cost Estimates Only)*

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Estimates of Annual Funding (Pilot Scale)</th>
<th>Estimates of Annual Funding (Full Scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create the Commercialization Partnership Board</td>
<td>$3M</td>
<td>$3M</td>
</tr>
<tr>
<td><strong>Talent</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create the Canada Commercialization Fellowships Program</td>
<td>$65M</td>
<td>$275M</td>
</tr>
<tr>
<td>Expand granting council programs to spur hiring of graduates with commercialization skills</td>
<td>$15M</td>
<td>$40M</td>
</tr>
<tr>
<td>Encourage and celebrate young Canadians who aim for success in business, science and technology</td>
<td>$15M</td>
<td>$60M</td>
</tr>
<tr>
<td>Develop and retain talent for success in a global marketplace</td>
<td>$50M</td>
<td>$190M</td>
</tr>
<tr>
<td><strong>Research</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create the Commercialization Superfund</td>
<td>$50M</td>
<td>$250M</td>
</tr>
<tr>
<td>Expand federal programs supporting firms in proof of concept/principle</td>
<td>$10M</td>
<td>$50M</td>
</tr>
<tr>
<td>Create the Canadian SME Partnerships Initiative</td>
<td>$50M</td>
<td>$200M</td>
</tr>
<tr>
<td><strong>Capital</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create the community angel networks and angel co-funding program to improve access to early-stage angel financing and expertise</td>
<td>$20M</td>
<td>$40M</td>
</tr>
<tr>
<td>Make tax changes to encourage foreign investment</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Total Annual Funding Requirement</strong></td>
<td><strong>$278M</strong></td>
<td><strong>$1.108B</strong></td>
</tr>
</tbody>
</table>

*These are investments that the panel believes would bring private sector returns through enhanced productivity but that would still need to be reviewed annually. In addition, approximately $1 million in one-time funding is required to review Canada’s expansion-stage venture capital market. The CPB should regularly review the outcomes achieved through these initiatives to ensure that goals are being met. Based on these reviews, the CPB should make recommendations to expand, modify or cancel initiatives as appropriate.
The return on these new investments will include stronger economies at the community, regional and national levels; more demand for highly qualified personnel, especially young people; a more vibrant research climate; and a stronger risk capital community. These represent necessary investments in Canada’s future in an extremely competitive world.

We believe that the steps we are recommending, reinforced by the measures discussed in the next section, will help improve the productivity vital to the quality of life of Canadians. They will help to reduce the standard of living divide between Canadians and Americans, estimated at US$8200 (GDP per capita at purchasing power parity).

Finland

The rapid growth of Finland’s high-technology economy is often seen as a testament to long-term strategic planning, systematic investment and the ability to adopt innovative policies more quickly than other nations. In the 1970s, Finland’s political leaders, research community and labour unions engaged in planning to focus R&D funding in electronics, biotechnology and material technology. Sustained government support paid off, as electronic-based exports grew from 4 percent of Finland’s economy in 1980 to 33 percent of all its exports in 2003.32 Today, Finland’s private and public sectors invest 3.5 percent of Finland’s GDP into R&D programs (the second-highest level in the world), and the proportion of the country’s population working as research scientists is the highest in the world.33


This report has presented a road map for action to increase commercialization in Canada. As set out at the beginning of this report, framework policies, competition, taxation, intellectual property and regulation are all instruments that can have a significant impact on demand for commercialization, and further work in these areas is essential. In reviewing these programs, it is critical that Canada address domestic issues with a clear eye on global opportunities – and global competition.

Improvements to Canada’s Regulatory System

The External Advisory Committee on Smart Regulation reported in September 2004 on how the federal government could redesign its regulatory system for the 21st century. This work on regulatory reform should help in identifying priorities for action on possible barriers to Canadian commercialization across all sectors of the economy. The CPB should review those recommendations and other regulatory issues that could influence achievement of Canada’s commercialization objectives. Possible questions could include the following:

• What approaches to regulation work to maximize incentives to innovate?

• How can Canada’s regulatory systems be better aligned with those of its major trading partners in order to open domestic and export doors for Canadian firms?

• Do Canada’s financial sector regulatory approaches influence commercialization?

Modernization of Canada’s Intellectual Property Laws

Many high-growth sectors rely heavily on intellectual property rights to secure financing and develop their products. This raises questions about the extent to which the Patent Act remains supportive of innovation and investment, especially in comparison with intellectual property legislation in other countries. While the federal government has minimal influence over intellectual property regimes in universities, these regimes are also seen as important in encouraging or discouraging commercialization-related research.

There exists a strong body of work on the role of intellectual property regimes on commercialization. In reviewing this field, possible questions could include the following:

• How can Canadian intellectual property protection ensure that firms reap the full benefit of their innovations?

• How can Canada get the most impact from the commercial potential of publicly financed research?

• With new technologies, such as biotechnology, posing challenges for Canada’s existing patenting system, is Canada’s intellectual property regime keeping pace with advances in technology?

• What steps will ensure competitive international protection for Canadian intellectual property?

• What approach to intellectual property protection for publicly funded research would ensure effective and efficient commercialization?
Improvements to Canada’s Tax Regime

A culture of innovation must be supported by an internationally competitive taxation regime. We recognize the steps that the federal and provincial/territorial governments have taken to reduce corporate and personal income taxes. But, even with these reductions, we agree with the C.D. Howe Institute’s recent statement that “Canada has the second-highest effective tax rate on capital (taking corporate income and other capital-related taxes into account) out of 36 developed and leading developing competitors.”34

We also recognize the debate over the effectiveness and possible changes to the scientific research and experimental development (SR&ED) tax credit program. Possible questions to consider regarding Canada’s tax regime could include the following:

- What specific tax measures, such as changes to the SR&ED tax credit, or additional tax credits, would encourage greater investments in commercialization?
- What tax measures would expand access to angel and venture capital investment or stimulate greater protection of companies’ intellectual property?
- What tax measures would increase the market research performed by firms?
- Would changes to the capital cost allowance for advanced machinery and equipment have a material impact on Canadian commercialization?
- What are the respective strengths and weaknesses of specific tax approaches in achieving policy goals, compared with using direct program spending?

Increasing Competitive Intensity within the Canadian Marketplace

The panel strongly believes that competition is an important driver of commercialization. A competitive marketplace with capable rivals and sophisticated customers provides incentives for innovation. It encourages the kind of business discipline that leads to stronger Canadian companies that are ready to face international competition. While we have addressed some specific elements of competition in our other business framework comments, we believe the CPB should look at issues such as action under the Agreement on Internal Trade in order to reduce barriers to business activity among provinces/territories, and at measures to improve competition in areas exclusively under federal jurisdiction. Possible questions could include the following:

- What demonstrable effects does the current state of competition in Canada have on innovation and commercialization?
- What steps to improve the competitive environment for business, including steps that may require action by the provinces/territories, would generate the most results through commercialization?

Other Topics

During the course of its work, the panel has identified a number of other issues that also merit attention. These are described in Appendix H — Additional Issues for Longer-Term Consideration.

We began this report by stating that Canada is at a crossroads. We conclude it by stating that Canada must take advantage of the unique opportunity presented by its current economic strength and invest in our ability to transform knowledge into market successes.

Canada needs an approach to policy in support of commercialization that is private-sector-focused and market-driven. This is what will deliver the best results for business while meeting the public interest demands of accountability and transparency. It will produce a more efficient, more integrated system — one that can meet immediate needs, while providing a clear road map for decision making and implementation in the future.

This means changing how we think and act, becoming global leaders and striving for continual improvement.

Canada must become more entrepreneurial. It must accelerate the ability of its innovative and creative thinkers to succeed and be rewarded. It must build on its competitive advantages. And it must do so by focusing on people and excellence.

Further, Canada must refine and enhance how it supports its commercialization and innovation infrastructure. Making it more adaptable and flexible will allow the private sector, governments, academic institutions and other groups to be better able to react to changing conditions, moving aggressively and seizing new opportunities.

It is in Canada’s focus and execution that it will differentiate itself from its competitors around the globe.

Finally, Canada must nurture true networks among businesses, government and academia, as well as between the people and institutions that provide the money and expertise that accelerate commercialization: venture capital and institutional investors, pension funds, and angel investors in Canada. It must also nurture networks with the international marketplace in all its dimensions.

All of this will lead to an environment in which highly qualified personnel see and create opportunity and in which demand for innovation is increased. The result will be increased productivity.

To achieve all this, government, business and the education and research communities must work together as never before, united in a common cause to define Canada as an innovative country with products, services and processes that can compete and win in global markets.
UNESCO SCIENCE REPORT 2010
The Current Status of Science around the World
While Canada is a relatively solid performer in science, technology and innovation, it needs to aim for a bigger role on the world stage.

Paul Dufour
INTRODUCTION

The present chapter describes the evolution over the past decade of the science and innovation systems of Canada, a northern nation that has traditionally relied on its natural resources and geography for socio-economic progress. We shall examine what Canada has done to mobilize the international currency of knowledge and skills for competitive advantage while managing its more conventional assets in a sustainable and responsible manner. We shall also point to some longstanding structural characteristics of the economy that have contributed to the continued poor performance of industrial research and development (R&D) and innovation.

By default, the public research sector – and institutions of higher education in particular – has largely come to be seen by policy-makers as a surrogate for innovation. Canada is unquestionably a major player in global science, with considerable assets. We shall describe some of the more recent experiments that have made Canada one of the world’s premier science and research players. We shall also underscore the current challenges Canada faces in overcoming the principle weaknesses in its approach to innovation. This comes at a time when the world is faced with a severe economic recession. Canada has not been spared but has perhaps been affected to a lesser extent than other countries. Thanks to its comparative strengths – a banking system among the strongest in the world and a real estate market that has avoided the excesses seen in other countries – a more rapid recovery is predicted. Furthermore, core inflation is at its lowest point in over 50 years and commodity income from the country’s considerable natural resources has helped to mitigate the negative impact on the economy. As in other countries, unemployment has risen – it stood at 7.9% nationally as of June 2010. In recent years, real GDP has grown (Figure 1), from CAN$1.091 trillion in 2004 to CAN$1.226 trillion in 2008, with GDP per capita currently at approximately CAN$46,000 per annum. A two-year stimulus package of CAN$62 billion to 2010/2011 is in place, representing about 4.2% of GDP, with a deficit projected by the federal government at around CAN$50.2 billion in 2009/2010.1

1. In July 2009, the Bank of Canada declared that Canada was on the path to recovery from recession.

Figure 1: Annual growth in GERD and GDP in Canada, 1967-2007 (%)

Source: Statistics Canada
Canada is a G8 economy (Figure 2) with a population of 34 million in a North American integrated economy. An officially French and English bilingual nation, it has an ageing but highly educated and multi-ethnic population. Canada covers a huge land mass – second only to the Russian Federation in size – and is exposed to extreme climates, straddling as it does the Arctic Circle. Its vast territory is well connected by sophisticated information and communication technology (ICT) networks. Also of note is that Canada has no constitutionally defined division of labour in relation to science and technology (S&T), being a federated state which practices power-sharing among the central government, the ten provinces and three territories that make up its political landscape.

Canada has a number of structural and cultural characteristics that mark its approach to science and innovation. In recent years, basic questions have emerged as a result of the federal Science and Technology Strategy released by the minority Conservative Party government in May 2007 (Government of Canada, 2007). The strategy’s four principles are: promoting world-class excellence, focusing on priorities, fostering partnerships and enhancing accountability. For example, are priority areas sufficiently focused on future investments? If Canada wants to compete, how should it do so and on what basis? How does one assess impact? And what roles do skills, education, talent and ingenuity play in all of this? As the central government possesses no Ministry of Education and no full-time, dedicated Cabinet-level Minister for Science,2 these are indeed critical questions of national importance, particularly in the context of the current economic recession, major industrial restructuring and significant new investments in S&T and innovation by the US administration (see page 36).

As a result, a national debate has resurfaced on the potential loss of Canada’s brain power to its neighbour to the south and on Canada’s future global competitiveness. Furthermore, a recent report by the government’s Science, Technology and Innovation Council (STIC) has noted that, while Canada is a relatively solid performer in STI, it needs to aim for a bigger role on the world stage. As the report puts it, ‘while we have been good, we now need to be great’ (STIC, 2009).

TRENDS IN INNOVATION

The end of a long investment cycle?
Several observers have noted that a country like Canada, situated immediately to the north of the world’s largest knowledge superpower, cannot afford to remain complacent about its own approach to innovation. Over the dozen years since 1997, federal and provincial governments have invested a combined amount of well over CANS 20 billion in R&D (Table 1), much of it in the academic and medical research sectors but increasingly in specific targeted areas where Canada and its regions have a competitive advantage. These areas, notionally defined by the current federal S&T strategy, include natural resources and energy, environmental science and technologies, health and related life sciences and ICTs. Canada is also a global player in such disciplinary fields as astronomy and space science, clinical medicine and genomics, Earth sciences and mathematics (CCA, 2006). Between 2002 and 2008, the number of Canadian publications inventoried in the Science Citation Index rose from 30 305 to 43 539, an increase spread evenly across all major fields of science (Figure 3).

In terms of overall refereed journal publications, Canada ranks sixth in the world (Figure 4). Some 60% of Canadian scientific papers are co-authored with the country’s largest scientific partners, the United Kingdom and USA (Science-Metrix, 2008) [Table 2].
In part, this large-scale, long-term investment cycle in R&D since 1997 has come about through continuous budget surpluses over the decade leading up to the recession in 2008. As a result, Canada has been at the forefront of the G8 in terms of gross domestic expenditure on research and development (GERD) per capita in the higher education sector and is second only to Sweden among countries of the Organisation for Economic Co-operation and Development (OECD) in this category. R&D in the higher education sector now constitutes roughly 35% of the country’s total R&D performance (Figure 5).

However, other data cloud this rosy picture. Business R&D expenditure in Canada as a percentage of GDP declined by 20% from 2001 to 2007. Canadian industry’s spending on R&D was just over 1% of GDP in 2006, well below the OECD average of 1.56% and the US average of 1.84%. Business R&D represents only about 54% of R&D performed in the country and is concentrated in a handful of companies, with only 19 firms spending more than CAN$100 million per year on R&D (Figure 6). The top ten companies have carried out one-third of all R&D over the past two decades (OECD, 2008). Even more troubling, one firm, Nortel, responsible for a large portion of this one-third of business R&D, has been severely weakened by its inability to recover from the high-tech market crash in 2000–2001 and, more recently, from the global recession. In January 2009, facing flagging market demand, Nortel filed for bankruptcy protection, leading to most of its key assets being gradually sold off. Business R&D spending in the manufacturing sector especially appears to be in slow decline, although R&D in the services sector has maintained some staying power.

There are other worrying signs. The labour market demand for science and engineering graduate students appears to be weakening. Since 1984, relative labour productivity in Canada’s business sector has fallen from more than 90% of the US level to about 76% in 2007. Canada ranked 15th out of 18 countries in a recent assessment of growth in labour productivity. When compared to the USA, Canada has shown much slower growth in labour productivity since 2000 in three major sectors: manufacturing, information and culture; and finance, insurance and real estate. The average investment per worker in ICTs in Canada was only about 60% of the US level in 2007. In short, some have concluded that Canadian business – with a few notable exceptions – tends to be seen as a technology follower, not a leader.

Government investment choices

Historically, government investment in S&T has been largely a non-partisan issue. All political parties support it but to varying degrees and with a different emphasis from one period to another. For example, once it had absorbed a serious budgetary deficit, Canada’s previous Liberal Party administration (1993–2005) decided from 1997 onwards to invest in knowledge on a large scale relative to other discretionary expenditure, reasoning that fostering a sound knowledge economy would greatly benefit Canadians.

Table 1: Trends in GERD in Canada, 1999–2008

<table>
<thead>
<tr>
<th>GERD in CAN $ millions</th>
<th>GDP in CAN $ millions</th>
<th>GERD/GDP ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999 17 638</td>
<td>982 441</td>
<td>1.80</td>
</tr>
<tr>
<td>2000 20 556</td>
<td>1 076 577</td>
<td>1.91</td>
</tr>
<tr>
<td>2001 23 133</td>
<td>1 108 048</td>
<td>2.09</td>
</tr>
<tr>
<td>2002 23 536</td>
<td>1 152 905</td>
<td>2.04</td>
</tr>
<tr>
<td>2003 24 691</td>
<td>1 213 175</td>
<td>2.04</td>
</tr>
<tr>
<td>2004 26 763</td>
<td>1 290 906</td>
<td>2.07</td>
</tr>
<tr>
<td>2005 28 126</td>
<td>1 373 845</td>
<td>2.05</td>
</tr>
<tr>
<td>2006 28 599</td>
<td>1 449 215</td>
<td>1.97</td>
</tr>
<tr>
<td>2007 29 170</td>
<td>1 532 944</td>
<td>1.90</td>
</tr>
<tr>
<td>2008 29 487</td>
<td>1 600 081</td>
<td>1.84</td>
</tr>
</tbody>
</table>

Note: Data for 2007 and 2008 are preliminary.

Source: Statistics Canada

Table 2: Trends in scientific publications in international collaboration for G8 countries, 2002 and 2008

<table>
<thead>
<tr>
<th>Country</th>
<th>2002</th>
<th>2008</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>12 144</td>
<td>20 030</td>
<td>+65</td>
</tr>
<tr>
<td>France</td>
<td>19 782</td>
<td>28 046</td>
<td>+42</td>
</tr>
<tr>
<td>Germany</td>
<td>26 930</td>
<td>36 668</td>
<td>+37</td>
</tr>
<tr>
<td>Italy</td>
<td>12 553</td>
<td>19 027</td>
<td>+52</td>
</tr>
<tr>
<td>Japan</td>
<td>14 213</td>
<td>18 162</td>
<td>+28</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>8 884</td>
<td>8 778</td>
<td>-1</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>23 898</td>
<td>35 663</td>
<td>+49</td>
</tr>
<tr>
<td>USA</td>
<td>57 161</td>
<td>83 854</td>
<td>+47</td>
</tr>
</tbody>
</table>

Source: Knowledge Assessment Methodology database; Thomson Reuters Inc. Science Citation Database Expanded, compiled for UNESCO by the Canadian Observatoire des sciences et des technologies
To some extent, this investment has paid off but it has also raised expectations of continued funding on a similar scale. The current government has also supported new R&D investment under its federal Science and Technology Strategy released in May 2007. However, it has been criticized in the media as well as in some research circles for an overemphasis on investment in scientific infrastructure at the expense of more significant renewed programme funding for the three main grants councils – the Natural Sciences and Engineering Research Council (NSERC), the Canadian Institutes of Health Research, and the Social Sciences and Humanities Research Council – and other research funding institutions like Genome Canada. In the face of the ambitious research funding and aggressive science and education policy agenda announced by the Obama administration, some fear a loss of talent and research expertise to a re-energized US research system.

Over the past decade, a number of new science and innovation programmes and institutional projects have been successfully introduced into the research system. These include the 2000 Canada Research Chairs, the Networks of Centres of Excellence, the Canada Foundation for Innovation, Genome Canada and numerous scholarship programmes. These have been accompanied by funding increases for the three major grants councils for university research and by provisions for indirect research costs. In all, an estimated CAN$16 billion in new federal research funding has pushed Canada to the forefront of the international S&T arena but has also resulted in calls for greater accountability and for the socio-economic impact of S&T projects to be demonstrated.

A persistently poor R&D culture in much of the business sector

Focusing on supply issues is a constant reminder that demand for knowledge must also be well grounded. In Canada, this continues to be problematic. The debate over Canada’s weak business R&D is perennial, going back...
to the early 1960s (Dufour and de la Mothe, 1992). Whereas, in most leading developed economies, the private sector plays an active role in driving and championing the need for an enhanced innovative capability, in Canada, business leadership is largely lacking. In part, this is because many Canadian-based firms are weak performers of R&D. This is to some extent a function of their status as branches or plants of foreign-based multinationals but it can also be attributed to the fact that Canada has been a global commodity producer, an area where R&D has not been considered a major business input.\(^3\)

A 2009 study by the Council of Canadian Academies has argued that there is no single cause for weak innovation in Canada. Rather, a sound understanding and analysis of the factors that influence business decision-makers, sector by sector, is also required (CCA, 2009a). It has made the point rather convincingly that Canada’s productivity problem is actually a business innovation problem and that business strategies do not emphasize innovation as a key competitive tool. Canada’s place in ‘upstream’ North American industries and a small domestic market that is geographically fragmented provide less incentive for a business to innovate in order to survive. Others also argue that there is insufficient advocacy from the various private sector associations to invest in innovation and devote greater attention to the importance of innovation and research for competitiveness.

### Jump-starting the innovation process

Arguably then, the higher education research sector has come to be seen as a surrogate for industrial R&D in Canada, along with some key public technology institutions. There have been numerous attempts by successive governments at both the federal and provincial levels to shape new public sector levers to stimulate the commercialization of knowledge through public-private partnerships. One good example of this is the agreement negotiated by the federal government with the Association of Canadian Universities and Colleges (AUCC)...

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3. It should be noted, however, that multinational firms operating in Canada appear to invest more in R&D than their Canadian-owned counterparts.
in 2002; it stipulated that Canadian universities were to double the amount of research they performed and triple their commercialization performance, in addition to intensifying the training of graduate researchers and contributing to the socio-economic development of their communities. As a result of this entente, the AUCC has produced various accountability measures and benchmarks to monitor and update these commitments. For example, according to its data, the income received by Canadian universities from the commercialization of research results almost doubled between 2002 and 2006, while spin-offs from universities grew from 718 in 1999 to 1068 in 2006 (AUCC, 2008).

Another novel case can be found with the Networks of Centres of Excellence (NCE) programme mentioned earlier. A competitive-based initiative, the programme was launched in 1989 with the objective of not only developing a network of excellence around the country to address specific research challenges but also of working in concert with industry to generate practical applications from basic research programmes. There are now 20 NCEs, all chosen via a competitive process covering a gamut of strategic research areas across the country. They include three devoted explicitly to major social issues. By all accounts, the programme has met with considerable success. For example, according to a recent progress report on the federal S&T Strategy (Government of Canada, 2009) in 2006–2007, the NCEs have:

- partnered with close to 2 000 companies, government departments and agencies, hospitals, universities and other organizations in Canada and around the world;
- employed more than 6 000 researchers and highly qualified personnel;
- supported their scientists in filing 110 patents and publishing 4 309 papers in refereed journals;
- obtained or launched negotiations on 20 licenses and generated four spin-off companies.

Building on this model, the federal government has experimented with hybrid, more commercially driven...
designs to engage industry actively. In 2007, the Business-Led Networks of Centres of Excellence programme was announced to fund large-scale collaborative networks. These are expected to increase private-sector investment in research in Canada, support the training of skilled researchers and shorten the timelines between research and commercialization. Up to five centres are to be supported for four years through this new programme. Centres of Excellence in Commercialization and Research have also been created to the tune of CAN$350 million over five years. These advance research and commercialization of technologies, products and services in four priority areas identified by the 2007 federal Science and Technology Strategy. The first batch of these centres was simply announced by the federal government in 2007 but, since then, centres have undergone a selection process combining international peer review with advice from the private sector.

There have been other efforts to jumpstart the innovation process in Canada. These range from some of the most generous R&D tax credits in the world to new forms of venture capital support and even targeted research funds for automotive innovation, aerospace, forestry and defence – important employment sectors of the Canadian economy. In addition, given Canada’s tremendous scope in energy assets, investments have been made in energy research and technology, including the establishment of Sustainable Development Technology Canada in 2001, a foundation that supports groundbreaking technologies from the private sector in climate change, clean water and next-generation renewable fuels. Along with a Clean Energy Fund announced in 2009, more than CAN$3.5 billion has been invested in energy research and technology, with more likely to come.

The National Research Council of Canada, the premier technology motor of the public sector (with laboratories across the country), has also increased its financial support – to CAN$200 million for two years – for the well-established Industrial Research Assistance Program designed to help solve the innovation challenges of small and medium-sized companies. As of October 2009, this new funding had reached over 1,200 firms and created over 4,500 jobs on top of the 455 new graduates hired by small firms. In parallel, federal government laboratories in various areas that include natural resources, national defence, the environment, and agri-food and agriculture have developed initiatives to commercialize their technologies.

The three grants councils have also been responsive. For example, the Natural Sciences and Engineering Research Council has funded three strategic networks to focus on challenges in manufacturing, forestry and fisheries. Some of the provinces have also invested significantly in research and innovation. The province of Ontario has created a Ministry of Research and Innovation to focus the provincial government’s commitment to making innovation the driving force of Ontario’s economy. Alberta has announced a major initiative on clean energy and supports a four-part technology commercialization action plan. As for Quebec, it has introduced an ambitious CAN$1.16 billion science and research strategy that includes funding for participation in key international S&T ventures.

Despite all of these efforts to improve the demand for knowledge, including some new funds to foster industrial R&D internships for students wishing to work in the private sector, the overall weakness in private sector performance persists.
UNESCO SCIENCE REPORT 2010

PERSONNEL ISSUES

The need for a strong national agenda in higher education and research

In many respects, Canada has two Achilles Heels. The first, as we have seen, is the lacunae of aggressive private-sector commitment to innovation. The second is the lack of a strong national agenda for talent and science education when it comes to orchestrating effective skills, education and training for the 21st century. While education remains almost exclusively a provincial matter, responsibility for S&T and research are undefined constitutionally. As a result, different levels of government intercede with different instruments for varying outcomes. This makes for a complex web of actors and recipients, often with unco-ordinated leadership.

A landmark study in 1984 by the defunct Science Council of Canada on science education involving all jurisdictions made this point clearly (Science Council of Canada, 1984). Other studies have since pointed out the need for a pan-Canadian vision for education, research and skills. Furthermore, despite the occasional federal/provincial/territorial S&T ministerial meetings, Canada’s one and only attempt at a truly national S&T strategy, adopted by all levels of government in 1987, has long since lapsed.

Data show that enrollment in Canadian universities in the 2006/2007 academic year rose only 0.9%, the smallest rate since 2000. Of some concern is a persistent disaffection among students for the natural sciences and mathematics: in recent years, enrollment has fallen in several areas, including mathematics and computer and information sciences (Figure 7).

However, it is worth noting that Canadian secondary school pupils perform well in science, according to the OECD’s Programme for International Student Assessment. In 2006, they ranked third – after pupils in Finland and Hong Kong in China.

Taking full advantage of a highly educated foreign-born population

Nearly half (47%) of Canada's population of working age holds a tertiary degree. Canada’s large foreign-born population is also highly educated. The country has the highest ratio in the world of foreign-born PhDs to native PhDs and is second only to the USA for highly skilled foreign-born workers. Taking full advantage of the immigrant population for enhanced socio-economic development is a challenge.

Evidence shows that Canada succeeds in attracting highly skilled immigrants on a permanent basis but fares less well when it comes to attracting and retaining foreign students at advanced levels of education. In fact, one of the earlier policy experiments was structured precisely to address this question of retention: the CANS 2 billion Canada Research Chairs (CRC) Programme was designed in 2000 to attract top talent to Canada’s universities and keep them there. Two thousand CRCs have been allocated on a competitive basis to 70 participating universities across the country. The chairs are allocated according to a two-tier principle: CANS 200 000 per chair for established 'stars' for seven years, tenure that is renewable, and CANS 100 000 per year for five years for junior or rising stars. One of the features of this ongoing programme is that universities have to provide a strategic research plan on how they would allocate the chairs and in what areas. This requirement has encouraged Canadian universities to become more focused in some of their research. The success of this model has been adapted elsewhere around the globe and, in 2007, the International Development Research Centre, Canada’s premier research development agency, joined up with the CRC programme to create a new initiative for selected university chairs in the developing world. In 2009, under this programme, eight research teams were selected to receive up to CANS 1 million each over five years, each to address a key development challenge.

Other measures have been put in place under the 2007 federal Science and Technology Strategy. The Vanier Canada Graduate Scholarships Program supports 500 Canadian and international doctoral students each year with three-year scholarships valued at up to CANS 50,000 per annum. Launched in September 2008, these awards are expected to attract and support world-class doctoral students who demonstrate a high standard of scholarly achievement in graduate studies along with strong leadership skills.

Building on the CRC programme, a Canada Excellence Research Chairs Program was launched in 2009, with a budget of CANS 10 million over seven years to support 20 researchers and their teams in establishing research programmes at Canadian universities and research hospitals.

Provincial governments promoting an entrepreneurial culture

Provincial governments are active as well. Quebec has the highest provincial GERD/GDP ratio in Canada, at 2.7%. It is followed by Ontario at 2.3%. These two provinces, which contain most of Canada’s manufacturing heartland,
Canada

Figure 7: Enrollment in scientific disciplines in Canada, 2002/2003 and 2006/2007
Number of students and percentage of total university enrollment

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics, computer and information sciences</td>
<td>15,706</td>
<td>4,537</td>
</tr>
<tr>
<td>Agriculture, natural resources and conservation</td>
<td>14,592</td>
<td>34,262</td>
</tr>
<tr>
<td>Architecture, engineering and related technologies</td>
<td>81,096</td>
<td>86,313</td>
</tr>
<tr>
<td>Physical and life sciences and technologies</td>
<td>81,804</td>
<td>92,328</td>
</tr>
</tbody>
</table>

Note: 2005/2006 and 2006/2007 enrollments for the University of Regina are not available.
Source: Statistics Canada

dominate the provincial R&D landscape. Firms in Ontario account for 48% of total industrial spending in R&D, while those in Quebec account for 30% (Statistics Canada, 2009). For example, the Ontario government’s CAN$3 billion Innovation Agenda (Government of Ontario, 2008) provides funding for the development and teaching of commercial skills across sectors and disciplines. It supports programmes to spark the interest of young people in innovation. As well as providing funding for theoretical physics and quantum computing, Ontario invested CAN$100 million in an initiative centred on genomics research in 2009, along with a CAN$250 million Emerging Technologies Fund to be co-invested with venture capital funds for companies in clean technology, life sciences and digital media and ICTs.

Other provinces, such as Alberta, Quebec, British Columbia and Saskatchewan, are all actively engaged in promoting science and an entrepreneurial culture through science popularization, outreach and scholarships. Most provinces have embedded science and research functions in ministries responsible for small business, entrepreneurship or innovation. A few have S&T councils advising their government on emerging trends and new policy directions, among them British Columbia and Quebec. Alberta has adopted a new approach to innovation with the creation of Alberta Innovates, a set of four corporations that will address specific innovation challenges for the province.

Several provinces have research and technology councils that develop technology commercialization and cluster strategies to enhance innovation specific to their region, often in conjunction with federally funded research bodies located in their province or territory. Some of the regional agencies for economic development supported by the federal government are active in this arena. One example is the multimillion-dollar Atlantic Innovation Fund established in 2000, which supports research in the four Atlantic provinces: Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland and Labrador.

INVESTMENT IN INFRASTRUCTURE
Laying the foundations for innovation
Funding is a good start but researchers also need a well-appointed home if they are to be successful. In 1997, the federal government initiated an experiment that it dubbed the Canada Foundation for Innovation (CFI).
Despite its name, the programme is actually designed to ensure the provision of state-of-the-art research capacity, equipment and facilities to universities, colleges and hospitals across Canada. Envisioned to last for five years, with an initial investment of CAN$800 million, its success has been such that its lifespan will carry it beyond 2010 – with a combined projected investment of almost CAN$10 billion over the past decade. CFI is structured to leverage 60% of its funding from other sources, including the provinces. Since its inception, CFI has supported, through open competition, 6,000 projects at 128 research institutions in 64 Canadian communities (Government of Canada, 2009). An analysis of CFI’s impact over the past five years indicates that this new infrastructure has led to:

- the creation of more than 4,000 jobs in the public and private sectors;
- the training of almost 11,000 technical personnel;
- the generation of more than 9,000 research collaborations;
- the registration of 1,750 intellectual property rights claims;
- the development of 760 new or improved products, processes or services; and
- the creation of almost 200 spin-off companies.

Another major investment in infrastructure has come through the CANARIE Advanced Research Network, a sophisticated, ultra-high-speed broadband network linking the country’s universities, hospitals, federal laboratories and other facilities with top institutions around the globe. CANARIE received an additional CAN$120 million in the 2007 budget. In 2009, as part of a broader economic stimulus package, the federal government also invested CAN$2 billion for improvements to knowledge infrastructure in the country’s colleges and universities.

Several organizations have also called for greater attention to be paid to entrepreneurship and producing business, management and financial talent at Canada’s business schools. Virtually every study on competitiveness makes this point, arguing that innovation requires better-informed managerial talent, rather than solely investment

**Figure B: S&T labour force in Canada, 2006**

<table>
<thead>
<tr>
<th>Category</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science and engineering technologists</td>
<td>504,970</td>
</tr>
<tr>
<td>Computer and information systems professionals</td>
<td>387,685</td>
</tr>
<tr>
<td>Civil, mechanical, electrical and chemical engineers</td>
<td>120,260</td>
</tr>
<tr>
<td>Science and engineering managers</td>
<td>70,390</td>
</tr>
<tr>
<td>Other engineers</td>
<td>69,160</td>
</tr>
<tr>
<td>Physical science professionals</td>
<td>35,080</td>
</tr>
<tr>
<td>Life science professionals</td>
<td>29,455</td>
</tr>
<tr>
<td>Mathematicians, statisticians and actuaries</td>
<td>7,855</td>
</tr>
<tr>
<td>Science and engineering managers</td>
<td>120,260</td>
</tr>
<tr>
<td>Physics and engineering managers</td>
<td>70,390</td>
</tr>
<tr>
<td>Other engineers</td>
<td>69,160</td>
</tr>
<tr>
<td>Physical science professionals</td>
<td>35,080</td>
</tr>
<tr>
<td>Life science professionals</td>
<td>29,455</td>
</tr>
<tr>
<td>Mathematicians, statisticians and actuaries</td>
<td>7,855</td>
</tr>
</tbody>
</table>

Source: Statistics Canada
in more scientists and engineers. When a 2009 study by the Council of Canadian Academies examined how the research produced by Canadian business and finance schools was faring, it found that, while overall output from this research tended to rank above the world average in most traditional disciplines, there was a lack of explicit relevance to potential end-users (CCA, 2009).

SCIENCE GOVERNANCE

Science governance faces challenges of its own

Fixing and fuelling innovation systems also requires a sound regulatory environment, high technical standards and well-framed conditions to support the business environment. In a country with a long-standing social democratic tradition, informed advice and public engagement on the country’s future directions is a sine qua non condition. Sound scientific advice and a strong science and innovation culture are central to these tenets. Canada has experimented with various institutional forms of scientific advice in the past but few have survived. The longest-standing of these was the Science Council of Canada, which was closed by the federal government in 1992 after 26 years of providing a public face and dialogue on Canadian science policy.

In 2008, after a four-year experiment, the Office of the National Science Advisor (which had been set up under the former Liberal Party prime minister) was disbanded. Borrowing from similar models in other countries, the office had been an attempt to address an obvious gap in the government’s ability to mobilize effectively its advisory capacity internally on key public policy issues. Issues it actively supported over its short life-span include (Carty, 2008):

- the creation of the Canadian Academy of Science in 2005, now the Council of Canadian Academies, an independent organization with a 10-year grant endowment of CANS 30 million designed to assess the science underlying important public policy issues. The Council has produced several reports at the request of the government, following a landmark report in 2006 on the state of S&T in Canada (CCA, 2006) which formed the basis of the federal government’s strategy for priority-setting.4 Assessments published by the Council include the potential for gas hydrates in Canada, the impact of nanotechnologies on health and the environment, the sustainable management of groundwater, business innovation, the transmission of influenza and design options for a proposed new international Arctic research station. Other assessments on animal health and biodiversity are under way;

- advising on what became a CANS 156 million contribution to the International Polar Year (2007–2008), the largest ever global programme dedicated to polar research. Canada led 44 projects in this venture, which focused on the impact of climate change and adaptation measures, as well as the health and well-being of Northerners and Northern communities. This investment stimulated a major outreach programme in addition to mobilizing communities, researchers and the next generation of scholars in Arctic research. The government has also committed to establishing a world-class research station in the high Arctic, a feasibility study is currently being finalized on its potential location;

- in collaboration with the heads of the research councils and agencies, the development of a draft framework for the funding, evaluation and oversight of major Canadian investments in science and infrastructure. Since 2008, Canada has continued to support several such ventures, including NEPTUNE Canada, a CANG300 million public-private sector collaboration on the Pacific Coast involving Canada and the USA that will use a cabled observatory to expand knowledge of the ocean and ocean floor. Other projects include the Canadian Light Source in Saskatchewan, the Sudbury Neutrino Observatory in Ontario and a major contribution to the Large Hadron Collider near Geneva in Switzerland (see page 158);

- with the co-operation of aid agencies and other departments and agencies, the drafting of an action plan to help mobilize R&D to meet the needs of the developing world, especially in the context of Canada’s previous G8 commitments in health, agriculture and innovation for development in Africa. A multi-million dollar Development Innovation Fund was announced in 2007 to assist in funding breakthroughs in health and related areas for the benefit of developing countries. Canada’s International Development Research Centre (IDRC) was one of the first organizations to support the establishment of...
Africa’s Science and Technology Consolidated Plan of Action by the New Partnership for Africa’s Development (NEPAD), announced in South Africa in 2005 (see page 297);

In conjunction with other international obligations, the National Science Advisor worked closely with the international trade department to help design the International Science and Technology Partnerships programme (ISTP) that is now providing CAN$20 million for enhanced R&D partnerships with Brazil, China, India and Israel. The ISTP has led to over 30 funded joint projects with China and India (ISTP, 2009). Moreover, a new experiment in trilateral co-operation involving Canada, China and Israel in agri-innovation shows considerable promise for other such partnerships in the future (ISTP, 2009). In addition, the National Science Advisor helped to shape the Canada–California Strategic Innovation Partnership (CCSIP), which has since resulted in the creation of a bilateral Cancer Stem Cell Consortium announced by the Minister of Health and the Governor of California in May 2008. In December 2008, a CAN$2 million joint call for proposals was launched under the CCSIP, resulting in over 100 expressions of interest from some 23 Canadian universities.

In 2007, the federal government phased out several other S&T advisory groups, including the Council of S&T Advisors and the National Biotechnology Advisory Council. These were replaced with a new Science, Technology and Innovation Council (STIC), which has since resulted in the creation of a bilateral Cancer Stem Cell Consortium announced by the Minister of Health and the Governor of California in May 2008. In December 2008, a CAN$2 million joint call for proposals was launched under the CCSIP, resulting in over 100 expressions of interest from some 23 Canadian universities.

The STIC provides S&T advice on issues referred to it by the government, such as the design of new S&T scholarships or how to enhance Canada’s S&T role internationally. The council is mandated to produce a regular national report benchmarking Canada’s performance in S&T against international standards of excellence, the first of which was published in May 2009 (STIC, 2009). Unlike similar bodies in other jurisdictions, the public is not privy to the work of STIC, with the exception of its national report. STIC provides advice to the government on a confidential basis.

CONCLUSION

Looking forward

The next phase of Canada’s knowledge investment is unclear, in a rapidly changing S&T environment with diminishing expectations and new priorities, and amid pressing domestic and global demands. From 2001, when Canada’s R&D effort reached a high of 2.09% of GDP, GERD declined to 1.84% of GDP in 2008 (Table 1). Federal R&D expenditure is expected to drop to 2.6% in 2008/2009 from 2.9% the previous year. In 2008, direct federal funding of R&D amounted to CAN$5.2 billion, or just under one-sixth of the country’s total R&D funding. While the federal government’s overall spending on S&T was about CAN$9.9 billion in 2008–2009, S&T accounted for about 4.1% of the total federal government budget, down from 4.6% over the previous two years.

Responding in part to critics of its tepid investment to date, the federal government announced in March 2010 a suite of new innovation and research measures spanning 2010 and 2011. These include a five-year postdoctoral fellowship programme of CAN$45 million; small increases over two years to the grants councils (totalling CAN$32 million per year); a one-time investment of CAN$75 million to Genome Canada; CAN$135 million to the NRC for its regional innovation clusters; and CAN$50 million over the same period to TRIUMF, Canada’s premier national facility for nuclear and particle physics. The 2010 Budget also invested CAN$197 million over five years to develop the next-generation remote-sensing radar satellite: RADARSAT. A programme for college and community innovation will also receive an additional CAN$15 million per year and CAN$135 million in annual funding for two years has been earmarked for the regional development agencies to enable them to continue supporting innovation across the country. The proposed Canadian High Arctic Research Station received new funding for a pre-construction design phase and the ISTPP programme with India, China, Brazil and Israel was extended for another two years with an additional CAN$8 million. Nonetheless, with a looming austerity programme to reduce Canada’s budget deficit by 2016, many predict tougher times ahead for research and other areas of discretionary spending. The onus will be on the research and innovation community to continue to make its case.

There is an animated and re-emerging public policy debate at the moment on limiting potential brain drain, as US spending on R&D and other incentives are ramped up
Canada

in the world with other
countries. Government policies are increasingly focusing on the
trend to frame research for commercial results and direct
direct areas of priority. Nonetheless, even the co-founder of
Canada’s largest high-tech company, Research in Motion –
makers of the Blackberry – has warned of the perils of
ignoring basic research (Lazaridis, 2009). Mike Lazaridis has
invested over CAN$150 million of his personal fortune to
create the world-class Perimeter Institute for Theoretical
Physics (PI) and the Institute for Quantum Computing.
These are both located at Waterloo, Ontario, one of the
country’s most dynamic knowledge clusters. Some of the
funding for these two institutes has come from federal and
provincial governments.5

Canada’s structural weaknesses in competitiveness and
innovation remain but projects to enhance technology and
its commercialization are on the rise. These are still too few
and far between, however. If Canada is to maintain its current
level of prosperity, they will need to be expanded on, with all
relevant sectors working together. Examples of such projects
are:

- the Medical and Related Sciences (MaRS) Discovery
  District in Toronto;
- the biopharma and nanotechnology clusters in Quebec;
- the marine and oceans research complexes in Halifax and
  St John’s;
- the nanotechnology, energy and water research institutes
  in Alberta; and
- the biotechnology and bio-products cluster in
  Saskatchewan.

The mission of Canada’s over 200 federal laboratories, which
serve the public good in areas that include health, the
environment, agriculture and food safety, is changing as the
R&D capacity of these laboratories slowly erodes. In
recognition of this decline, these laboratories received a two
year injection of CAN$250 million from the federal
government to help cover the cost of deferred maintenance.
An expert panel appointed by the federal government in
2008 examined ways in which the federal laboratories might
better adopt new business models, in collaboration with
universities, and analysed various forms of privatization.

Several new models for partnership in the fields of materials,
geosciences and nanotechnologies are being put in place as
a result. One good example is the National Institute for
Nanotechnology, established in 2001 on the campus of the
University of Alberta with the support of the NRC and federal
and provincial governments.

Diversifying partners in scientific collaboration
Canada’s global partnerships are also shifting to address the
country’s changing domestic needs. A recent study has
demonstrated that, while the USA continues to be the
country’s largest S&T partner by far – in 2008, over 51% of
Canadian scientific papers were co-authored with US
researchers, streets ahead of the next biggest partner, the UK
(8.1%) – the fastest growth in bilateral scientific collaboration
is occurring with emerging Asian and Latin American
economies, as well as with some Nordic countries. These
countries include China, Finland, the Republic of Korea and
Norway (Science-Metrix, 2009).

With respect to multilateral membership of various ‘clubs’;
Canada continues to participate in such groups as the
Asia-Pacific Economic Cooperation (APEC), the
Organization of American States (OAS),6 the United
Nations, the Francophonie – bringing together French-
speaking countries – and the North Atlantic Treaty
Organization. Despite some significant earlier investment
in development research, there are signs of a slowdown, as
aid and capacity-building shift towards other geopolitical
priorities, among them Afghanistan and the Americas.
Canada’s expertise in supporting S&T for development was
put to the test with the G8 and G20 meetings in 2010, as it
sought to strengthen partnerships with Africa and other
developing regions in specific programmatic areas
associated with global health via the launch of the
Development Innovation Fund. Funding will be delivered
by Grand Challenges Canada, a programme instigated by
the federal government in 2008 and endowed with
CAN$225 million over five years. The programme will
‘support the best minds in the world as they search for
breakthroughs in global health and other areas that have the
potential to bring about enduring changes in the lives of the
millions of people in poor countries’ Grand Challenges
Canada will be implemented in collaboration with the
IDRC and the Canadian Institutes of Health Research.

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5. The origins and development of the Perimeter Institute are related well
in an interesting book by its former Executive Director (Burton, 2009).

6. See Annex I for the member countries of APEC and OAS.
Developing a science culture
In addition to the pursuit of priority-setting and the examination of its appropriate place in shaping future public policy and investment in innovation and R&D, other debates are emerging. These are centred on improving the science culture and outreach in the country, including by augmenting the participation of women and the Aboriginal population in the knowledge society (Dufour, 2009). Women account for 47% of the labour force and 57% of university graduates but only 20% of doctoral degrees awarded in science and engineering.

Some of the responsibility for Canada’s deteriorating appreciation of the value of knowledge centres on its lack of a science culture in its widest form, both in the political realm and among certain segments of the population and research community. There is an antagonism here between what some have termed a ‘politically clueless research community versus a scientifically illiterate political class’. A Science Media Centre has been proposed to improve science communication within the media. Efforts are also under way at various science centres and museums across the country to strengthen public understanding. Events include a National Science and Technology Week and a major physics festival organized by the Perimeter Institute. Some provinces, especially in Quebec, have long-standing traditions and tools in support of science outreach, given the promotion of science in the French language.

Overall, however, the science culture gap remains. The scientific communities must share some of the responsibility for this. Often poorly organized, with limited means of outreach and inadequate communication tools, the research lobbies are increasingly faced with having to make a better case for why the future of the country lies with more, rather than less, research and technology – innovation in its broadest sense.

The private sector is also struggling to be more effective in articulating its own needs and concerns over the lack of necessary resources and strategic vision. If it can succeed in forging stronger partnerships, while recognizing the value of adopting new business innovation models, the private sector can emerge as a stronger actor in the country’s competitive future.

With continued public policy leadership and by building on its considerable physical and intellectual assets within a larger societal debate on knowledge for development, Canada’s innovative path shows considerable promise as it sets out to enhance its reputation as a Northern Minerva.7

REFERENCES

7. Usually associated with the Roman goddess of wisdom, Minerva, this term was deployed to refer to the Royal Society of Canada at the turn of the last century.
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ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance of the following people in the preparation and editing of this chapter: Kevin Fitzgibbons from the Department of Foreign Affairs and International Trade Canada; Hamid Jorjani, Chair of the Sectoral Commission on Natural, Human and Social Sciences from the Canadian Commission for UNESCO; and Christina Stachulak from the Council of Canadian Academies.

WEBSITES

Statistics Canada: www.statcan.gc.ca
Industry Canada: www.ic.gc.ca
Council of Canadian Academies: www.scienceadvice.ca
Association of Universities and Colleges of Canada: www.aucc.ca
Foreign Affairs and International Trade Canada: www.international.gc.ca