

4.251

4.001

A closer look at regions and countries

2.003

1.955

1.245

0.3



*Science powers commerce
– but not only.*

Paul Dufour

A truck driver gives *Hitchbot*, the talking, hitchhiking robot, a ride part of the way to its destination, during a Canadian experiment to test public attitudes towards robots.

Photo: © Norbert Guthier: www.guthier.com

4 · Canada

Paul Dufour

INTRODUCTION

Priorities: job creation and balancing the books

When last we reviewed the Canadian science, technology and innovation (STI) scene in the *UNESCO Science Report 2010*, a federal Conservative government had been in power since 2006¹. Since then, Canada has weathered the fiscal downturn fairly well, in part because of its sound financial banking services industry but also because the Canadian economy relied heavily on its endowment of energy sources and other natural resources, assets that are always in demand in the fast-paced emerging global environment.

When the shockwaves from the US financial crisis turned a healthy budget surplus of CAN\$ 13.8 billion in 2006 into a budget deficit of CAN\$ 5.8 billion two years later, the government reacted by adopting a stimulus package in January 2009. This package encouraged consumer spending and investment through tax breaks and other measures, in an attempt to reverse the downturn.

The package was costly (CAN\$ 35 billion) and left the government deeper in debt: the deficit peaked at CAN\$ 55.6 billion in 2009–2010. Balancing the budget by 2015 became the cornerstone of the government's multi-year *Economic Action Plan* (2010), which promised 'responsible fiscal management' to ensure 'ongoing economic growth and job creation over the longer term'. In 2014, the government projected that the deficit would fall to CAN\$ 2.9 billion by 2014–2015, with a return to a budget surplus the following year. In 2015, the latter is very much in doubt. In order to meet its deficit target, the government sold its remaining shares in the General Motors bailout of 2009. However, as oil prices have

1. The Conservative Party came to power in the 2006 federal election. Initially, a minority government, it won its first majority government in the 2011 elections. Stephen Harper has been prime minister since 2006.

plummeted since mid-2014, it is not clear what impact this will have on the overall fiscal health of the Canadian economy.

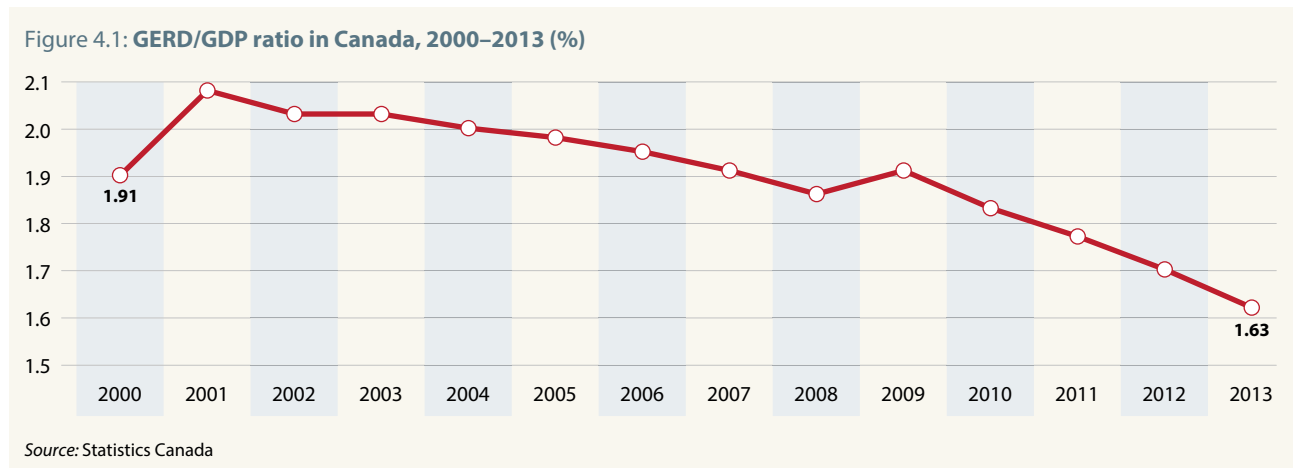
One of the government's key strategies has been to create jobs² by expanding trade. In his introduction to the *Global Markets Plan* adopted in 2013, the Minister of International Trade Ed Fast recalled that 'today, trade is equivalent to more than 60% of our annual GDP and one in five Canadian jobs is directly linked to exports'. The main goal of *Canada's Global Commerce Strategy* (2007) was to 'extend our reach to new emerging markets'; by 2014, Canada had concluded free trade agreements with no fewer than 37 countries, including a major deal with the European Union (EU). Its successor, the *Global Markets Action Plan* (2013), fine-tuned this strategy by eliminating trade barriers and cutting red tape to boost trade with established and emerging markets³ considered to hold the greatest promise for Canadian business.

Concerns about public interest science, business R&D and education

The government's incremental approach to policy-making over the past decade has translated into a lack of bold moves to stimulate funding for science and innovation. The organizational ecology of science and technology (S&T) has undergone some change, with a growing focus on economic returns from investment in knowledge. In parallel, gross domestic expenditure on research and development (GERD) as a percentage of GDP has been dropping (Figure 4.1).

2. The unemployment rate has remained steady since 2000, at between 6% and 8% of the active population. In April 2015, for instance, 6.8% of Canadians were unemployed (Statistics Canada).

3. The following emerging markets are considered as being priorities for foreign direct investment, technology and talent and/or part of regional trading platforms: Brazil, China (including Hong Kong), Chile, Colombia, Indonesia, India, Israel, Malaysia, Mexico, Peru, the Philippines, Republic of Korea, Saudi Arabia, Singapore, South Africa, Thailand, Turkey, United Arab Emirates and Viet Nam



UNESCO SCIENCE REPORT

Some challenges addressed in the *UNESCO Science Report 2010* have not been tackled and others are emerging. Two important weaknesses persist. The first is the lacunae of aggressive private-sector commitment to innovation. Canada continues to slide in overall global competitiveness rankings, in large part because of its underinvestment in innovation. According to the latest *World Competitiveness Report* (WEF, 2014), Canada's private-sector spending on R&D ranks just 27th in the world, compared to 19th for university–industry collaboration on R&D. For government procurement of advanced technology – a key driver of technological innovation in the world's most competitive economies –, Canada ranks 48th.

The second weakness concerns 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. With a number of indicators suggesting a decline in the prestige of higher education in Canada, this is becoming an urgent issue.

A third vulnerability has emerged since the release of the *UNESCO Science Report 2010*. Since the adoption of the multi-year austerity budget in 2010, the government

has been downsizing science agencies and departments. Recent surveys of Canada's scientific community reveal acute concerns at the impact of cuts on public interest science and basic science, as well as on Canada's international standing.

The present chapter will focus largely on analysing these three challenges. To set the scene, we shall begin by examining what the data tell us.

TRENDS IN R&D

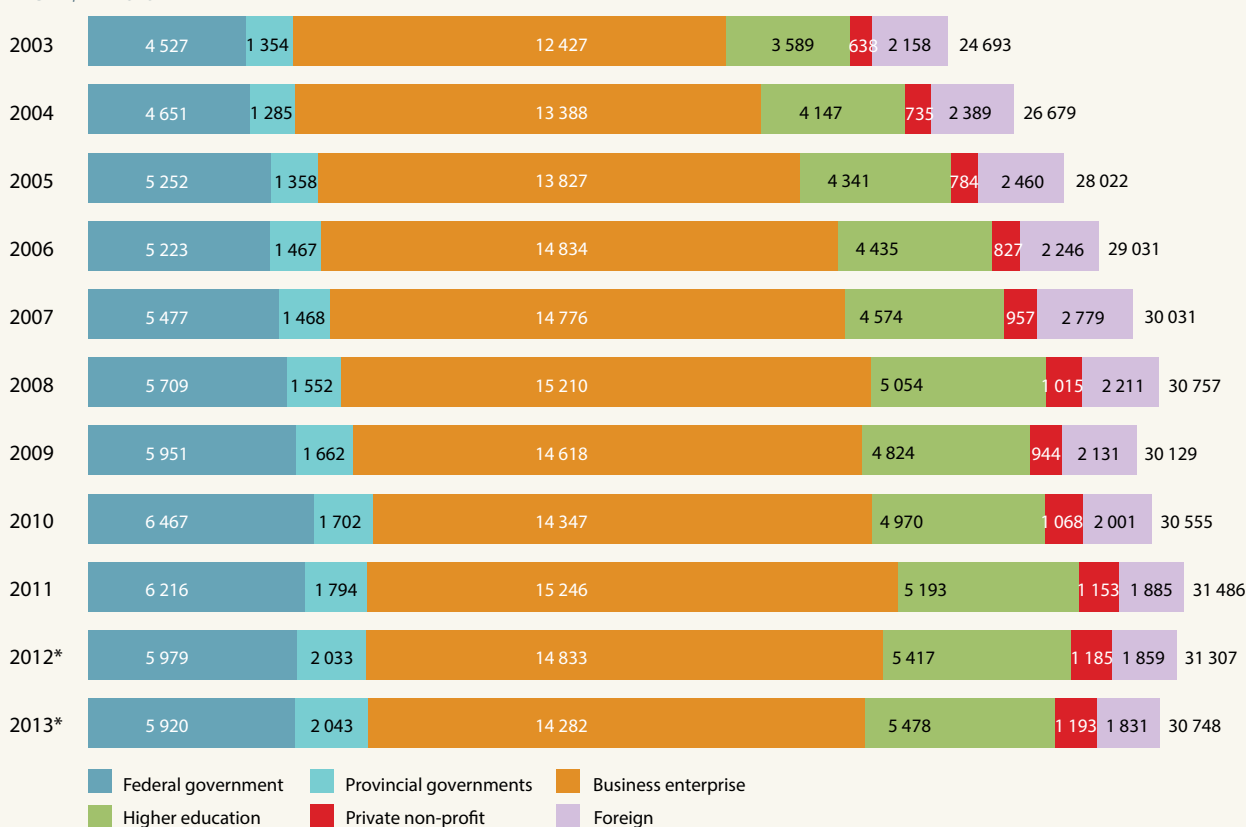
Canada's R&D effort at its lowest level for a decade

At 1.63%, Canada's GERD/GDP ratio sank to its lowest ebb in a decade in 2013. This is because the rise in GERD since 2004 (15.2%) had failed to keep pace with GDP (+42.9%). Between 1997 and 2009, R&D had been buoyed by continuous budget surpluses then by the federal stimulus package in 2009. GERD had even peaked in 2001 at 2.09% of GDP (Figure 4.1).

Between 2010 and 2013, the trend went into reverse. Federal in-house R&D became a casualty of the government's determination to balance the budget through its *Economic Action Plan* (2010). Government funding of R&D sagged by

Figure 4.2: GERD in Canada by funding sector, 2003–2013

In CAN\$ millions



Source: Statistics Canada

* preliminary data

just over CAN\$ 600 million, or over 10%, and continues to decline, with projected spending in 2013 of CAN\$ 5.8 billion (Figure 4.2). Some infrastructure projects are nevertheless being pursued for specialized facilities. For instance, a global High Arctic Research Station is being established in Canada's high north, the participation of Canada in the Thirty Metre Telescope has received a boost of CAN\$ 243.5 million over ten years and Canada's National Science and Technology Museum will be closed until 2017 for refurbishment.

The end to stimulus spending coincided with a 10.6% increase in GDP between 2008 and 2012; it is the combination of these two factors which drove the GERD/GDP ratio down to 1.63% in 2013.

A worrying slump in industrial R&D

It is a characteristic of Canadian science that the federal government agencies fund about one-tenth and universities four-tenths of all R&D. Much of the country's R&D effort relies on the dynamism of the business enterprise sector, which funds and performs the other half. The slump in industrial R&D in recent years is thus a worrying trend: in 2013, business-financed R&D accounted for 46.4% of overall spending, compared to 51.2% in 2006. Over the same period, foreign funding sources also shrank from 7.7% to 6.0% of the total, according to the UNESCO Institute for Statistics.

A 6.9% decline in federal funding of R&D is the main contributor to a stagnant year for Canadian R&D in 2014, according to the latest data from Statistics Canada. The agency released a brief report in January 2015 which projected

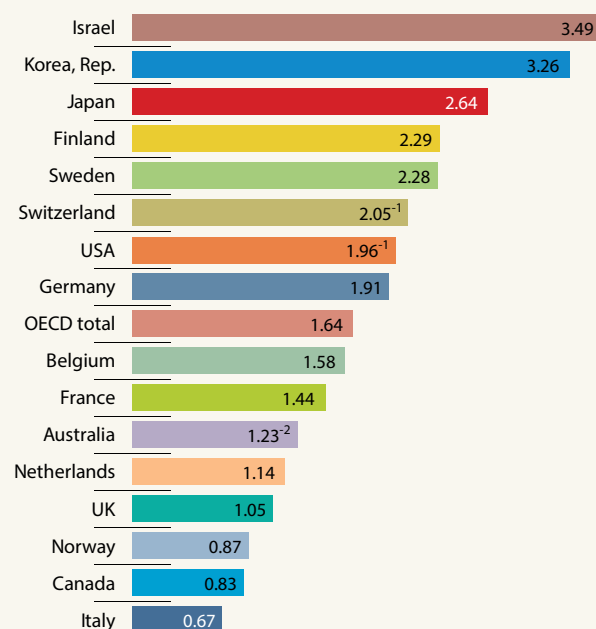
Table 4.1: GERD intentions in Canada by performing sector and source of funds, 2013 and 2014 (%)

	2013	2014	
Research and development spending intentions	CAN\$ millions		% change
Total, performing sector	30 748	30 572	-0.6
Business enterprises	15 535	15 401	-0.9
Higher education	12 237	12 360	1.0
Federal government	2 475	2 305	-6.9
Provincial government and provincial research organizations	339	338	-0.3
Private non-profit	161	169	5.0
Total, funding sector	30 748	30 572	-0.6
Business enterprises	14 282	14 119	-1.1
Federal government	5 920	5 806	-1.9
Higher education	5 478	5 533	1.0
Provincial government and provincial research organizations	2 043	2 066	1.1
Foreign	1 831	1 842	0.6
Private non-profit	1 193	1 207	1.2

Note: Components may not add up to totals because of rounding.

Source: Statistics Canada, January 2015

Figure 4.3: Business expenditure on R&D in Canada and other OECD countries as a share of GDP, 2013 or closest year (%)



-n = data are for n years before reference year

Source: UNESCO Institute for Statistics, August 2015

CAN\$ 30.6 billion in R&D spending in 2014, down marginally from CAN\$ 30.7 billion the previous year (Table 4.1).

This situation contrasts with that of other members of the Organisation for Economic Co-operation and Development (OECD), where the GERD/GDP ratio has recovered to pre-2008 levels. Among the G7 countries, only Canada registered declines between 2008 and 2012. Business expenditure on R&D (BERD) tells a similar story (Figure 4.3). Canada's BERD/GDP ratio peaked at 1.3% in 2001 before falling to 0.8% by 2013. In the OECD, BERD has increased from 1.4% on average in 2004 to 1.6% in 2013. Sectors that have experienced an erosion in R&D spending in Canada include pharmaceuticals, chemicals, primary metals and fabricated metals.

The cutback in industrial R&D spending has also taken its toll on the number of personnel engaged in R&D. Between 2008 and 2012, their number dropped from 172 744 to 132 156, representing a 23.5% decline in industrial R&D jobs. According to the most recent analysis by Statistics Canada, the number of R&D personnel in industry declined by 13 440 (9.2%) between 2011 and 2012, the second largest drop since 2008–2009 when 17 560 jobs were shed (Table 4.2).

Industry has not been the only sector to experience job losses, according to the latest data from Statistics Canada. There were fewer R&D personnel of all types in the federal and provincial governments in 2012 (Table 4.2).

Table 4.2: R&D personnel in Canada by sector, 2008–2012

Sector	2008	2009	2010	2011	2012
Federal government	16 270	17 280	17 080	16 960	16 290
researchers	7 320	7 670	8 010	7 850	7 870
technicians	4 700	5 170	4 900	4 760	4 490
support staff	4 250	4 440	4 170	4 350	3 930
Provincial governments	2 970	2 880	2 800	2 780	2 780
researchers	1 550	1 500	1 600	1 600	1 620
technicians	890	880	770	750	750
support staff	530	500	430	420	420
Business	172 740	155 180	144 270	145 600	132 160
researchers	98 390	93 360	94 530	97 030	88 960
technicians	52 080	47 190	38 570	39 290	32 950
support staff	22 280	14 630	11 180	9 280	10 240
Higher education	62 480	60 180	67 590	70 010	71 320
researchers	49 450	47 350	53 970	56 090	57 510
technicians	6 790	6 680	7 150	7 310	7 250
support staff	6 240	6 150	6 470	6 610	6 550
Private non-profit	2 190	1 240	1 300	1 240	1 390
researchers	500	340	530	520	590
technicians	900	470	540	500	510
support staff	790	430	230	220	290
Total	256 650	236 760	233 060	236 590	223 930
researchers	157 200	150 220	158 660	163 090	156 550
technicians	65 350	63 380	51 930	52 620	45 950
support staff	34 090	26 150	22 470	20 880	21 430

Source: Statistics Canada, CANSIM table 358-0159; *Research Money*, 22 December 2014

POLICY ISSUES IN INDUSTRIAL R&D

Weak business innovation translates into poor productivity growth

The perennial weakness of Canada's innovation performance by the private sector remains a major challenge. A synthesis report from the Council of Canadian Academies makes for depressing reading (CCA, 2013a). This document summarizes the main findings of seven different reports, from which two main conclusions emerge: Canadian academic research, overall, is relatively strong and well-regarded internationally. Canadian business innovation, by contrast, is weak by international standards; this is the primary cause of Canada's poor productivity growth.

The report asks (CCA, 2013a):

How has Canada's economy sustained relative prosperity, despite weak innovation and correspondingly feeble productivity growth? The answer is that Canadian firms have been as innovative as they have needed to be.

Until the early 2000s, their competitiveness was supported by an ample labour supply and a favourable exchange rate, which made productivity growth less urgent. Since then, the boom in commodity prices has supported Canadian incomes in the aggregate.

The report notes that Canada's fundamental challenge will be to transform its commodity-based economy into an economy capable of providing a larger number of markets with a greater variety of goods and services, where firms must compete primarily through product and marketing innovation. As more Canadian firms develop strategies that focus on innovation out of sheer necessity, they will create a much more powerful 'business pull' on Canada's strong S&T capacity.

Indeed, a second report by the Council of Canadian Academies on *The State of Industrial R&D in Canada* has concluded that Canadian industrial R&D remains weak for a

host of complex, often poorly understood reasons, although four key industries display considerable strength (CCA, 2013b):

- aerospace products and parts manufacturing;
- information and communication technologies (ICTs);
- oil and gas extraction; and
- pharmaceutical drug manufacturing.

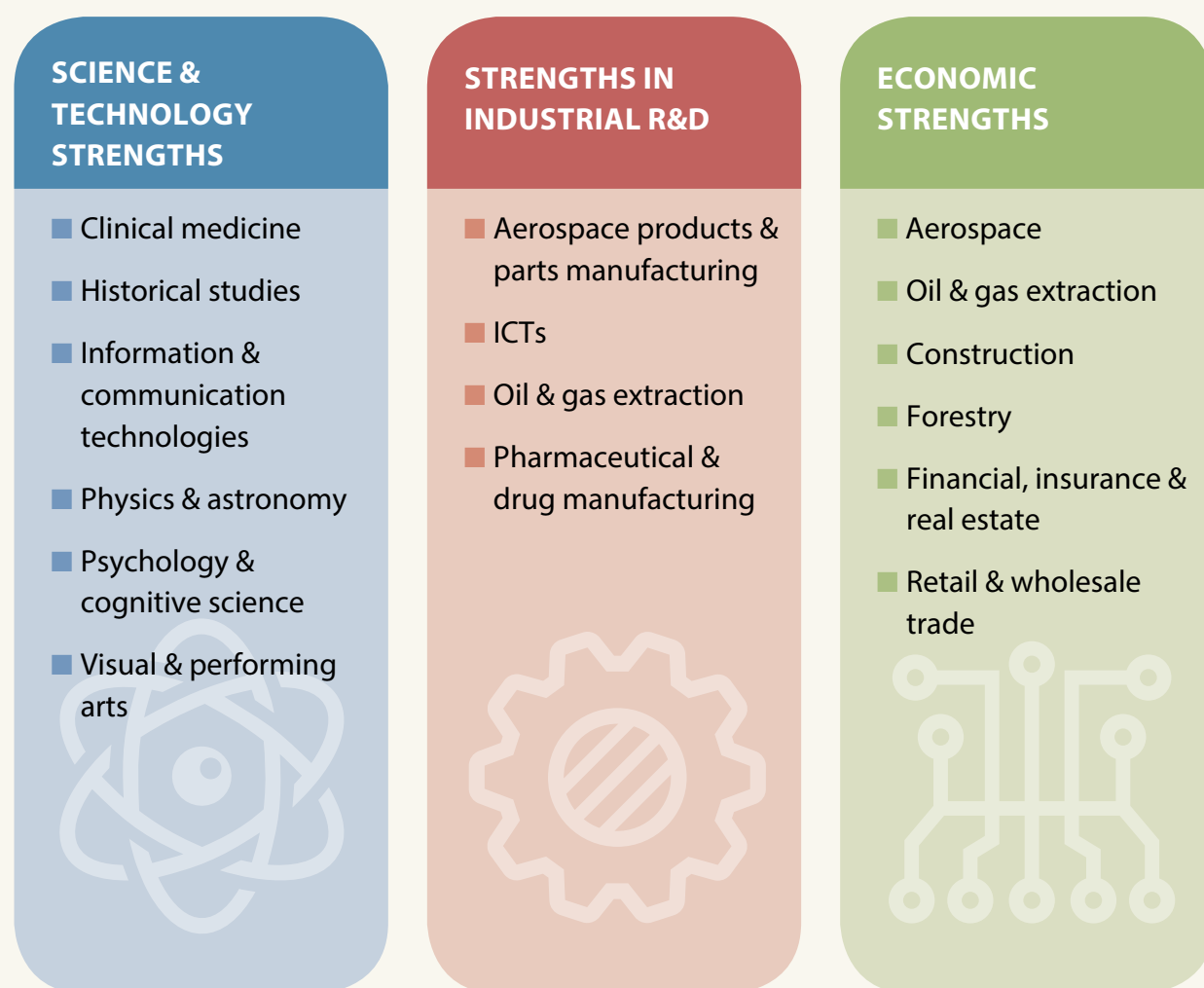
The panel's report found that, whereas R&D activity is extensive and spread across a wide range of industries, the relationship between R&D and S&T is asymmetrical. When examined by geographical location, the panel found that Canada's strengths in industrial R&D were clustered in certain parts of the country. Ontario and Quebec are dominant in aerospace; the majority of the ICT industry is found in Ontario, Quebec and British Columbia; oil and gas

are most prevalent in British Columbia and Alberta; and pharmaceuticals are most often located in Ontario, Quebec and British Columbia.

The report goes a step further and examines the alignment of strengths in industrial R&D with strengths in S&T and economics (Figure 4.4). It points out that, whereas there is some congruence between these areas, there is a significant lack of alignment that is not fully understood (CCA, 2013b):

With Canada's strong post-secondary education system and a foundation of world-class university research, the underpinnings for robust investment in industrial R&D exist. But attempting to connect such scientific strength and industrial R&D in a direct, linear relationship is overly simplistic, particularly as the R&D-intensive industries [count] for a smaller part of the Canadian economy than of other advanced economies.

Figure 4.4: Canada's strengths in S&T, industrial R&D and economics



Source: adapted from CCA (2013b)

How best to incite private investment in high-potential companies?

Along with some of the provinces, the federal government has been experimenting with different mechanisms to help reshape the business culture in this area. These have had limited success. For example, in January 2013, the government announced its *Venture Capital Action Plan*, a strategy for deploying CAN\$ 400 million in new capital over the next 7–10 years to leverage private sector-led investment in the form of venture capital funds.

Within this *Action Plan*, the government allocated CAN\$ 60 million in 2013 over five years, with an additional CAN\$ 40 million in 2014, to help outstanding incubator and accelerator organizations expand their services to worthy entrepreneurs. The Canada Accelerator and Incubator Program (CAIP⁴) subsequently made a call for research proposals on 23 September 2013 which attracted close to 100 applicants. CAIP is delivered by the National Research Council's Industrial Research Assistance Program, which evaluated these proposals on the basis of strict eligibility and selection criteria, including:

- the extent to which the project would encourage the growth of early-stage firms that represent superior investment opportunities;
- the potential of the project to develop entrepreneurial networks with other important firms and organizations, in order to provide entrepreneurs with a broader range of specialized services;
- the ability of the organization to demonstrate matching resources, either financial or in-kind (i.e. mentoring resources, administrative support) for the proposed activities; and
- a credible demonstration that the proposed activities would be incremental to existing operations.

An 'unnecessarily complicated' funding system

The private sector's reluctance to invest in high-potential companies has been a subject for debate in recent years. When Tom Jenkins submitted his panel's review of federal support for R&D to the Minister of State for Science and Technology in October 2011, he observed that, 'relative to the size of the Canadian economy, government support for business R&D in Canada is among the most generous in the world, yet we're near the bottom of the pack when it comes to seeing business R&D investment... What we found was a funding system that is unnecessarily complicated and confusing to navigate' (Jenkins *et al.*, 2011). One of the

panel's key recommendations was to create an Industrial Research and Innovation Council to deliver the federal government's 60 business innovation programmes – spread over 17 departments at the time. The government has not heeded this advice.

The *Venture Capital Action Plan* received mixed reviews, with some questioning the wisdom of using taxpayer money to nurture venture capital funds when this role fell naturally to the private sector.

In the longer-term, any attempt to develop more evidence on what works for Canada's unique knowledge economy will require a more thoughtful and co-ordinated approach than the *Venture Capital Action Plan*. Indeed, a report exploring ten policy criteria that could provide a more robust framework for innovation policy in Canada has been developed recently by scholars (University of Ottawa, 2013). Their report draws on evidence spanning 60 years to establish these ten criteria, which include:

- the policy should not prejudge the practical value of any category of knowledge;
- the policy should enable measurements that encompass the process of innovation (and not just the input and output); and
- the policy should favour 'open' knowledge regimes over 'proprietary' ones.

Science diplomacy to commercial ends

By 2014, half of Canada's scientific papers were co-authored by foreign partners, compared to an OECD average of 29.4% (Figure 4.5). Canada's collaboration rate with its closest partner, the USA, has been in decline: 38% of international papers were co-authored with US scientists in 2000 but only 25% in 2013, according to Science–Metrix.

In Canada, research partnerships and science diplomacy are increasingly being tied to trade and commercial opportunities. It is revealing that Canada's innovation network is managed by the Trade Commissioner Service at the Department of Foreign Affairs, Trade and Development, rather than being placed in the foreign service. This mega-department was created within Canada's *Economic Action Plan 2013* by amalgamating the Department of Foreign Affairs and International Trade and the Canadian International Development Agency, which had been in existence since 1968.

Two recent schemes illustrate the trend towards commercializing science diplomacy: the International Science and Technology Partnerships Canada (ISTPCanada) programme and the Canada–EUREKA partnership.

4. CAIP is providing support over a five-year period in the form of non-repayable contributions of up to CAN\$ 5 million a year to a limited number of best-in-class accelerators and incubators.

Box 4.1: Canada, China and Israel to share agro-incubator

In September 2013, Canada, Israel and China agreed to establish a joint incubator for the development and commercialization of agricultural technologies derived from collaborative research.

The incubator has since been established in the Yangling Agricultural Hi-tech Industries Demonstration Zone, known as the 'agricultural epicentre of China'. The incubator will enable commercial firms from all three countries to engage in collaborative R&D while connecting them to market opportunities and accelerating the commercialization of emerging agro-technologies. In 2012, Canadian agricultural exports to China exceeded CAN\$ 5 billion.

At the signing of the agreement, Dr Henri Rothschild, President and CEO of International Science and Technology Partnerships Canada and of the Canada–Israel Industrial R&D Foundation, observed that 'the resulting innovations will open up new Asian markets for collaborators, while enabling the development of the sustainable use of marginal lands, improved food quality and safety'.

Mr Michael Khoury, Consul for Economic Affairs at the Consulate General of Israel, welcomed the incubator as an opportunity for Israel 'to build on our collaboration with Canada and China to date and bring our multidisciplinary strengths to bear on this critical sector'.

Mr Wang Jun Quan, Deputy Director-General of the Administrative Committee of the Yangling Agricultural High-tech Industries Demonstration Zone, expressed pride at hosting the incubator and at facilitating collaboration with innovators from Canada and Israel. 'This centre will address the agricultural needs of Yangling and further establish this region as a global hub for agro-innovation', he said.

Source: ISTP Canada press release, 3 October 2013

ISTPCanada was launched in 2007 to 'connect Canadian innovators to global R&D partners, funding and markets'. The programme was mandated by the Department of Foreign Affairs, Trade and Development to facilitate new R&D partnerships between Canadian companies or research institutions (including universities) and their counterparts from four key trading partners: Brazil, China, India and Israel. Three of Canada's ten provinces participated in the programme: Alberta, British Columbia and Ontario. Between 2007 and March 2012, ISTPCanada developed 24 early-stage partnerships with China, 16 with India, 5 with Brazil and a further 5 multilateral activities with all three countries. See Box 4.1 for an example. It also funded 29 bilateral R&D⁵ projects: 17 with China, 8 with India and 4 with Brazil. ISTP covered up to 50% of the Canadian costs of approved joint research projects proposed by companies, universities/colleges and private research institutes. It claimed an almost four-fold leverage on every dollar invested in R&D projects; thus, it estimates that the CAN\$ 10.9 million it invested in R&D projects between 2007 and 2012 generated CAN\$ 37.9 million. ISTPCanada shut down in 2015, owing to lack of support from the responsible government department.⁶

5. ISTPCanada's main partners are: in China, the Ministry of Science and Technology and China Association for International Exchange of Personnel; in India, the Global Innovation and Technology Alliance, Department of Science and Technology and Department of Biotechnology; and in Brazil: the São Paulo Research Foundation (FAPESP) and Minas Gerais Research Foundation (FAPEMIG).

6. In a premonitory interview published in the 10 February 2015 issue of *Research Money*, CEO Pierre Bilodeau commented that ISTPCanada's future looked uncertain, as money and time were running out to renew its mandate. After no further funding was forthcoming, ISTPCanada closed its office in April 2015.

The Canada–Eureka partnership gives Canadian companies greater access to European markets. Eureka is a pan-European intergovernmental initiative designed to support the competitiveness of European companies by fostering market-oriented R&D via international collaboration. The partnership agreement was signed on 22 June 2012 in Budapest (Hungary), the National Research Council having been designated Canada's National Project Coordinator Office for Eureka. At the signing, Gary Goodyear, then Minister of State for Science and Technology, said that 'our government's top priority is the economy – creating jobs, growth and long-term prosperity for Canadian workers, businesses and families. Through our participation in the Eureka Initiative, Canadian companies will be better positioned to access international markets and accelerate technology development leading to commercialization.'

Small innovative Canadian companies have rapidly taken advantage of Canada's status as an associate member of the Eureka network. By September 2014, 15 projects had been launched for the development of technologies ranging from virtual machining to water desalination. Valued at more than CAN\$ 20 million, these market-driven industrial R&D projects have helped Canadian firms partner one-on-one, and in clusters, with companies from Europe but also from Israel and the Republic of Korea.

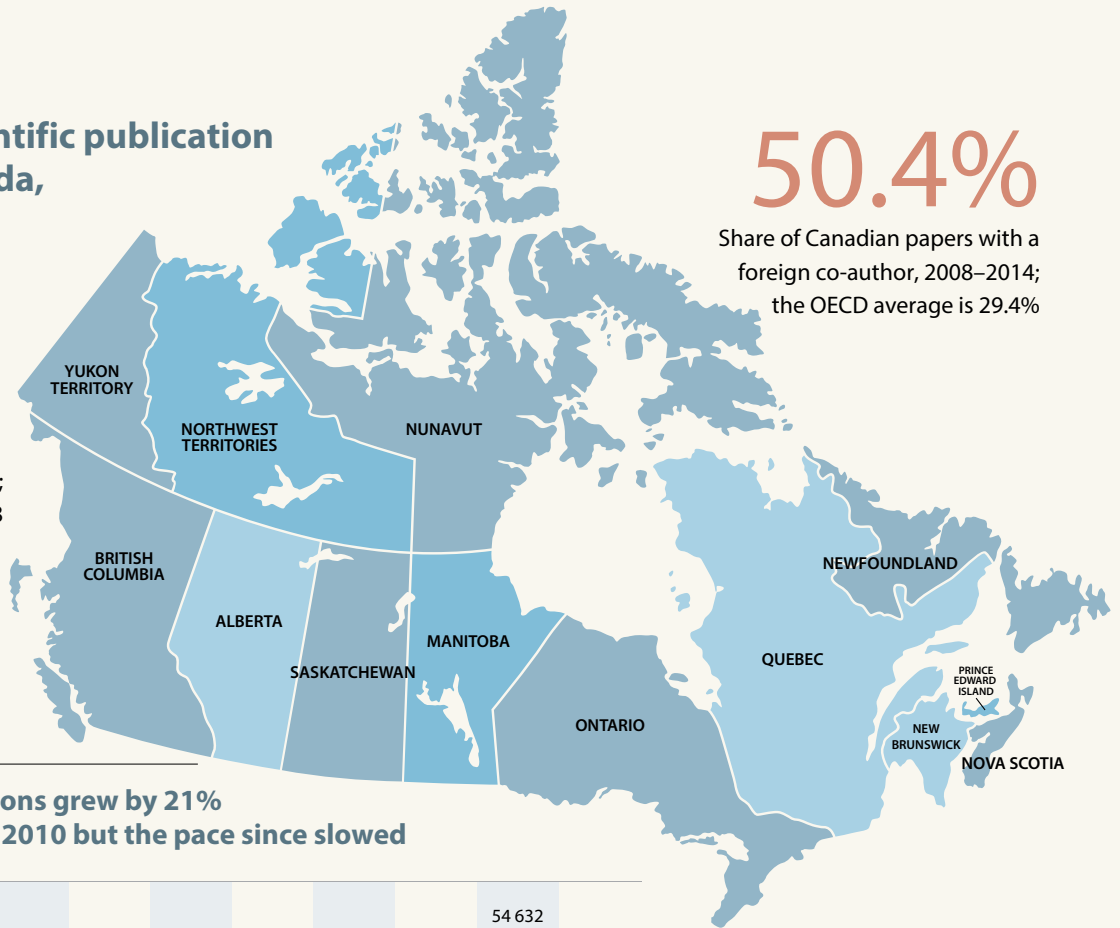
Figure 4.5: Scientific publication trends in Canada, 2005–2014

1.25

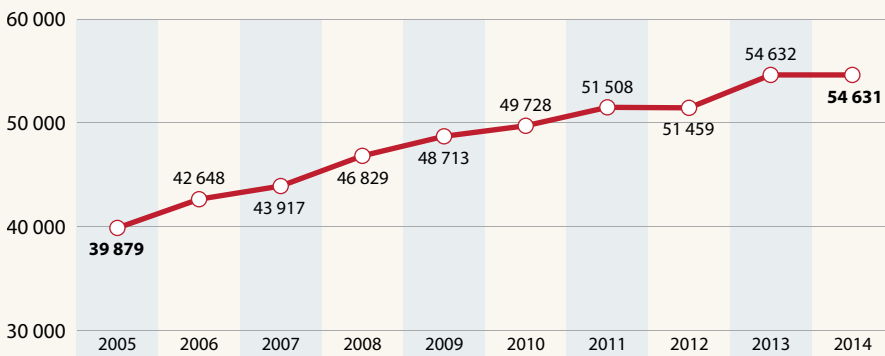
Average citation rate for Canadian publications, 2008–2012; the OECD average is 1.08

50.4%

Share of Canadian papers with a foreign co-author, 2008–2014; the OECD average is 29.4%



Canadian publications grew by 21% between 2005 and 2010 but the pace since slowed

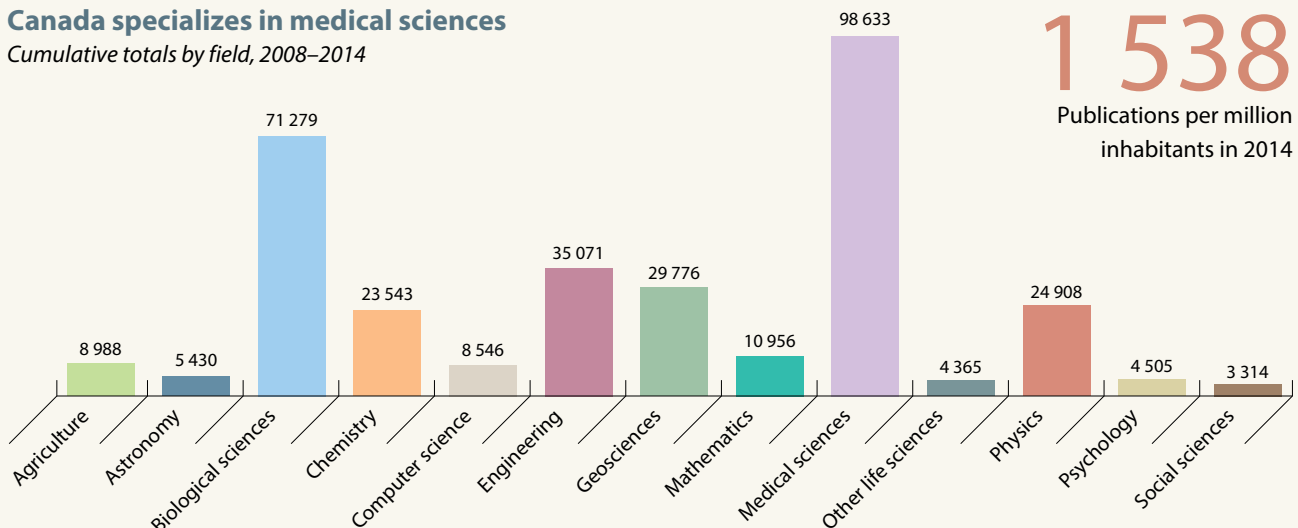


13.1%

Share of Canadian papers among 10% most-cited, 2008–2012; the OECD average is 11.2%;

Canada specializes in medical sciences

Cumulative totals by field, 2008–2014



1 538

Publications per million inhabitants in 2014

Note: Totals exclude unclassified articles.

Canada publishes most with US partners

Main foreign partners, 2008–2014 (number of papers)

	1st collaborator	2nd collaborator	3rd collaborator	4th collaborator	5th collaborator
Canada	USA (85 069)	UK (25 879)	China (19 522)	Germany (19 244)	France (18 956)

Source: Thomson Reuters' Web of Science, Science Citation Index Expanded, data treatment by Science–Metrix

POLICY ISSUES IN PUBLIC INTEREST SCIENCE

Budget cuts: a threat to Canada's global knowledge brand?

Canada's global knowledge brand is at risk. Government science and federal scientists have become a target for cuts. This has led to a first-ever mobilization of different interests to parry this troubling trend. The budget cuts are partly a consequence of the government's austerity budget but they also reflect an ideological bent that is predisposed to downsizing the public service. In an unprecedented series of documented public cases, the Canadian government has been accused of eroding support for public good science and even of muzzling its own scientists (Turner, 2013).

The Professional Institute of the Public Service of Canada (PIPSC) has catalogued the concerns of government scientists through two surveys. The first of these drew over 4 000 responses (PIPSC, 2013). It found that that nearly three out of every four federal scientists (74%) surveyed believed the sharing of scientific findings had become too restricted in the past five years; nearly the same number (71%) believed political interference had compromised Canada's ability to develop policy, law and programmes based on scientific evidence. According to the survey, nearly half (48%) were aware of actual cases in which their department or agency had suppressed information, leading to incomplete, inaccurate or misleading impressions by the public, industry and/or other government officials.

The second survey⁷ (PIPSC, 2014) argued that continued cuts within government science would further affect the government's ability to develop and implement evidence-based policies. *Vanishing Science: the Disappearance of Canadian Public Interest Science* observed that, 'between 2008 and 2013, a total of CAN\$ 596 million (in constant 2007 dollars) has been cut from science and technology budgets at federal science-based departments and agencies and 2 141 full-time equivalent (FTE) positions have been eliminated' (PIPSC, 2014).

The report stated that these cuts 'have resulted in the loss of whole programmes, including the Environment Canada-funded National Roundtable on the Environment and the Economy – for 25 years the leading federal advisory panel on sustainable development –, the Hazardous Materials Information Review Commission and the Canadian Foundation for Climate and Atmospheric Sciences, as well as the Ocean Contaminants and Marine Toxicology Program'

7. Invitations to participate in the online survey of federal scientists were sent to 15 398 PIPSC members – scientists, researchers and engineers – engaged in scientific work in over 40 federal departments and agencies. Of these, 4 069 (26%) responded (PIPSC, 2014).

funded by the Department of Fisheries and Oceans (PIPSC, 2014). See Figure 4.6 and Table 4.3.

The report opined that 'the worst is yet to come. Between 2013 and 2016, a combined CAN\$ 2.6 billion will be cut from 10 federal science-based departments and agencies⁸ alone, including a projected 5 064 FTE positions' (PIPSC, 2014). According to the UNESCO Institute for Statistics, 9 490 FTE researchers were employed in the government sector in 2010 and a further 57 510 in the university sector.

The report expressed concern that a recent shift in budget priorities towards greater support for commercial ventures would be detrimental to basic science and public interest science. It cited a slated 'decrease in internal S&T funding'⁹ of CAN\$ 162 million in 2013–2014, much of which is devoted to public health, public safety and the environment, compared to a CAN\$ 68 million increase in support for commercial ventures' (PIPSC, 2014). The authors cited a public opinion poll by Environics in November 2013, in which 73% of respondents felt that the top priority for government scientific activity should be the protection of public health, safety and the environment (PIPSC, 2014).

The survey also reflected federal scientists' concerns that new departmental policies on intellectual property and obtaining permission to publish, as well as restrictive policies on travel to international conferences, were compromising Canada's international scientific collaboration (PIPSC, 2014). Indeed, a recent report assessing the media policies of federal science departments had this to say (Magnuson-Ford and Gibbs, 2014):

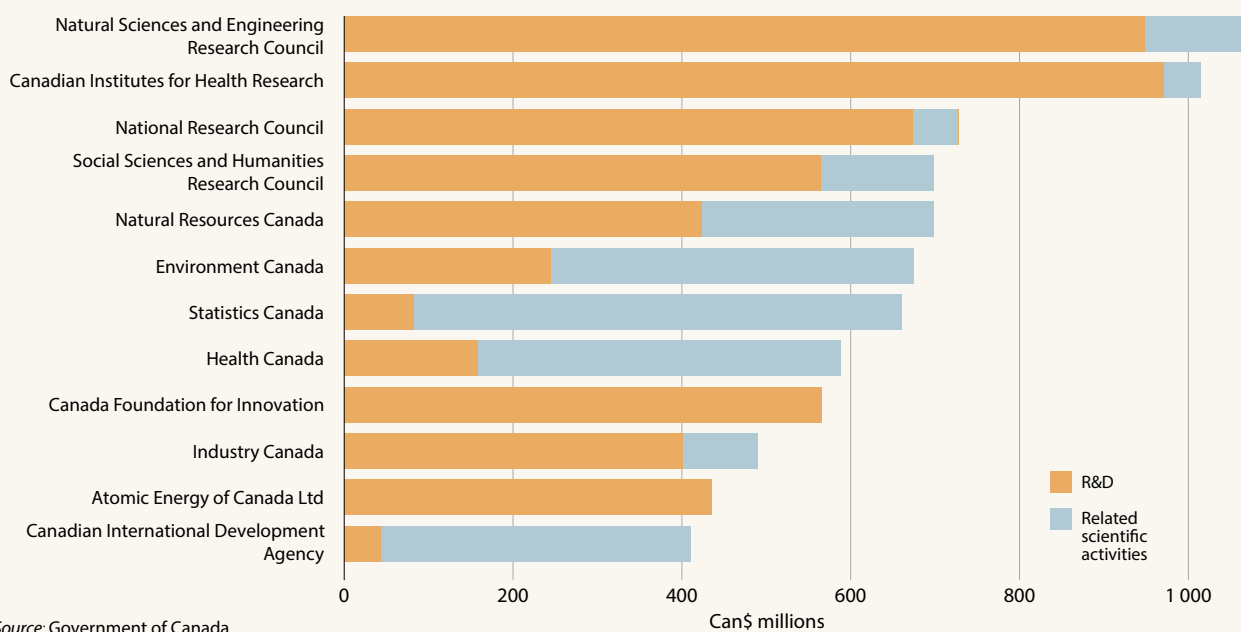
- Media policies in Canadian federal science departments were graded for openness of communication, protection against political interference, rights to free speech and protection for whistleblowers. Overwhelmingly, current policies do not support open communication between federal scientists and the media.
- Government media policies do not support open and timely communication between scientists and journalists, nor do they protect scientists' right to free speech.
- Government media policies do not protect against political interference in science communication.
- Over 85% of departments assessed (12 out of 14) received a grade of C or lower.

8. Agriculture Canada, Canadian Food Inspection Agency, Canadian Space Agency, Environment Canada, Fisheries and Oceans Canada, Health Canada, Industry Canada, National Research Council, Natural Resources Canada, Public Health Agency of Canada

9. Internal science refers in the present chapter to R&D conducted within science-based departments and agencies.

UNESCO SCIENCE REPORT

Figure 4.6: Major Canadian federal science departments and agencies by spending intentions for 2012



Source: Government of Canada

Table 4.3: Canadian federal S&T spending by socio-economic objective, 2011–2013

	2010/2011		2011/2012		2012/2013	
	Intramural	Extramural	Intramural	Extramural	Intramural	Extramural
	CAN\$ millions					
Total	2 863	4 738	2 520	4 381	2 428	4 483
Exploration and exploitation of the Earth	90	77	86	92	59	93
Transport	64	56	60	58	51	49
Telecommunications	46	52	41	35	34	35
Other infrastructure and general planning of land use	44	76	42	37	35	43
Control and care of the environment	200	227	208	225	121	251
Protection and improvement of human health	280	1 432	264	1 415	240	1 512
Production, distribution and rational utilization of energy	717	269	545	257	561	161
Agriculture	360	179	354	154	409	1603
Fisheries	7	29	7	21	6	17
Forestry	70	90	69	58	70	54
Industrial production and technology	206	801	182	799	153	937
Social structures and relationships	156	222	125	243	141	264
Space exploration and exploitation	78	228	74	268	61	195
Non-oriented research	247	938	240	641	211	636
Other civil research	21	4	14	2	16	1
Defence	276	57	211	76	258	71

Note: Federal S&T spending is the sum of spending on R&D and related scientific activities. Non-programme (indirect) costs are excluded from intramural expenditure.

Source: Statistics Canada, August 2014

The federal government's response to the survey

As a partial response to these critiques, the federal government instituted a confidential examination of government science in mid-2014, led by an expert panel reporting to a group of deputy ministers responsible for science and research. The review was designed to provide an informed external perspective of government science and to come up with ideas and approaches for performing science differently in science-based departments and agencies to meet current and future challenges, while recognizing the nature and value of internal science. The expert panel offered its confidential advice in late 2014. It is unclear whether any action has been taken since on the basis of this report.

In October 2013, the federal government announced its intention to launch a revised federal STI strategy to refresh its seven-year old predecessor outlined by the prime minister in May 2007. A short discussion paper accompanied consultations in January 2014 which took place under the aegis of the former Minister of State for Science and

Technology, Greg Rickford¹⁰. He was replaced in March 2014 by another junior science minister, Ed Holder, who has inherited the file.

In December 2014, Prime Minister Harper launched the revised strategy, entitled *Seizing Canada's Moment: Moving Forward in Science, Technology and Innovation*. This is essentially a progress report on what the government has undertaken since 2007. There is no earmarked funding for any of the fresh commitments.

The new strategy differs from its predecessor announced in 2007, in that innovation has been added as its central pillar (Table 4.4). *Seizing Canada's Moment* states that 'the 2014 Strategy puts innovation front and centre – in fostering business innovation, in building synergies with Canada's research capacities and in using its skilled and innovative workforce. It emphasizes the need for

¹⁰ In May 2014, Greg Rickford took over the joint portfolio of Minister of Natural Resources and Minister for the Federal Economic Development Initiative for Northern Ontario; the latter initiative had been entrusted to him in 2011.

Table 4.4: Canada's federal priorities for 2007 and 2014

Federal S&T strategy of 2007		Federal S&T strategy of 2014	
Priority area	Subpriorities	Priority area	Subpriorities
Environmental science and technologies	<ul style="list-style-type: none"> ■ Water: health, energy, security ■ Cleaner methods of extracting, processing and using hydrocarbon fuels, including reduced consumption of these fuels 	Environment and agriculture	<ul style="list-style-type: none"> ■ Water: health, energy, security ■ Biotechnology ■ Aquaculture ■ Sustainable methods of accessing energy and mineral resources from unconventional sources ■ Food and food systems ■ Climate change research and technology ■ Disaster mitigation
Natural resources and energy	<ul style="list-style-type: none"> ■ Energy production in the oil sands ■ Arctic: resource production, climate change adaptation, monitoring; ■ Biofuels, fuel cells and nuclear energy 	Natural resources and energy	<ul style="list-style-type: none"> ■ Arctic: responsible development and monitoring ■ Bio-energy, fuel cells and nuclear energy ■ Bio-products ■ Pipeline safety
Health and related life sciences and technologies	<ul style="list-style-type: none"> ■ Regenerative medicine ■ Neuroscience ■ Health in an ageing population ■ Biomedical engineering and medical technologies 	Health and life sciences	<ul style="list-style-type: none"> ■ Neuroscience and mental health ■ Regenerative medicine ■ Health in an ageing population ■ Biomedical engineering and medical technologies
Information and communication technologies	<ul style="list-style-type: none"> ■ New media, animation and games ■ Wireless networks and services ■ Broadband networks ■ Telecom equipment 	Information and communication technologies	<ul style="list-style-type: none"> ■ New media, animation and games ■ Communications networks and services ■ Cybersecurity ■ Advanced data management and analysis ■ Machine-to-machine systems ■ Quantum computing
		Advanced manufacturing	<ul style="list-style-type: none"> ■ Automation (including robotics) ■ Lightweight materials and technologies ■ Additive manufacturing ■ Quantum materials ■ Nanotechnology ■ Aerospace ■ Automotive

Source: compiled by author

businesses of all sizes to define and implement for themselves the science, technology and innovation they require to compete nationally and internationally.' Importantly, the strategy exhorts a sort of volunteerism by the business sector in reshaping its approach to investing in innovation. As such, it leaves the market to develop its own model.

In the meantime, public policy initiatives targeting STI are being put forward on several fronts, in the hope of effecting change by moral suasion. We shall briefly discuss some key topics currently under debate.

A desire to become a 'global energy superpower'

Early on in his mandate, Canada's current prime minister argued that Canada was aiming to become a global energy superpower.¹¹ Indeed, the government's preoccupation with finding new energy markets for oil and gas – especially the Alberta oil (tar) sands – has been remarkable but not without controversy both in Canada and abroad, as illustrated by Canada being named Fossil of the Year by environmentalists at several international meetings on climate change¹².

Not all sectors of the Canadian economy have fared as well as oil sands. Since 2002, there has been a remarkable increase in the real value of Canada's exports from the energy, metals and minerals, industrial and agricultural sectors, and a considerable drop in exports from the electronics, transportation, consumer goods and forestry sectors. In 2002, just under 13% of Canadian exports were energy-related products; by 2012, that proportion had grown to over 25%. From 1997 to 2012, oil's national share of commodity production value rose from 18% to 46%, nearly as much as the economic value generated from natural gas, forestry, metals and mining, agriculture and fishing combined. Many manufacturing companies, especially in the hard-hit automobile and consumer goods sectors, have retooled, in order to serve the resource sector, further contributing to an economy that is increasingly unbalanced and reliant on commodities; for over a decade now, R&D conducted by the private sector in the energy sector has been heavily concentrated in oil and gas.

Some attention has been paid to clean energy...

Leaving aside the use of conventional energy, some attention has also been paid to clean or renewable energy (Figure 4.7). In 2008, the federal government announced a green energy target: by 2020, 90% of all electricity generated in Canada was to come from non-greenhouse gas emitting sources. These sources include nuclear energy, clean coal, wind and hydroelectricity. By 2010, 75% of electricity was generated from these sources.

In the 2009 budget, the federal government created a Clean Energy Fund of more than CAN\$ 600 million to fund various projects, with the majority of the money (CAN\$ 466 million) going to carbon capture and storage projects. Canada also has programmes designed to support various forms of renewable energy, including wind energy, small hydropower, solar thermal, solar photovoltaic, marine energy, bio-energy and nuclear.

The Program of Energy Research and Development (PERD) is operated by Natural Resources Canada to advance key clean energy technologies that will contribute to a reduction of greenhouse gas emissions. PERD funds R&D performed by 13 federal departments and agencies, which are at liberty to collaborate with partners from industry, funding agencies, the university sector and associations.

Provincial governments have also played a strong role in energy production. Some have also invested in schemes to stimulate energy research. Quebec, for example, has a well-developed clean-tech cluster that is supported through various programmes and instruments. British Columbia has developed a bio-energy strategy designed to ensure that biofuel production meets 50% or more of the province's renewable fuel requirements by 2020; develop at least 10 community energy projects that convert local biomass into energy by 2020; and establish one of Canada's most comprehensive provincial biomass inventories of waste to energy opportunities. In the absence of federal leadership on climate change and energy, several provinces have also developed their own carbon pricing schemes.

In June 2014, Canada's Minister of Natural Resources co-chaired a national roundtable discussion on energy innovation in Canada, along with the Chair of Sustainable Development Technology Canada. The national roundtable was the sixth and final roundtable in a series of thematic roundtables held across the country since November 2013. Each event focused on a specific area of energy technology: distributed power generation; next-generation transportation; energy efficiency; long-term R&D opportunities and; unconventional oil and gas, including carbon capture and storage.

The roundtables focused largely on identifying barriers to accelerating energy innovation in Canada and how best to align efforts and enhance collaboration, in order to make Canada more competitive both domestically and abroad. A number of prevailing themes emerged from these discussions, including:

- building national leadership to promote innovation by engaging key players within governments, utilities, industry and academia;

11. Remarks by the Prime Minister of Canada, St Petersburg G8 Summit, 2006

12. In 2011, Canada became the first signatory to withdraw from the Kyoto Protocol to the United Nations Framework Convention on Climate Change, an agreement with binding targets adopted in 1997. The Kyoto Protocol expired in 2012.

- enhancing alignment, co-ordination and collaboration to maximize the impact of investment in innovation;
- providing certainty through policy measures;
- enhancing market access opportunities to foster a domestic market and support companies in demonstrating their technologies at home;
- greater information-sharing to break down barriers; and
- addressing energy literacy and consumer awareness through education.

The Government of Canada plans to use the discussions from these roundtables as a guide to identifying the best means of collaborating with private and public sector groups interested in promoting energy innovation in Canada.

Sustainable Development Technology Canada has been a key player in the energy debate. Created in 2001, this non-profit foundation finances and supports the development and demonstration of clean technologies. As of December 2013, 57 of Sustainable Development Technology Canada's more mature companies had received CAN\$ 2.5 billion in follow-on financing. The foundation operates three funds:

- the Sustainable Development Tech Fund has used CAN\$ 684 million allocated by the federal government to support 269 projects that address climate change, air quality, clean water and clean soil;
- the NextGen Biofuels Fund supports the establishment of first-of-a-kind large demonstration-scale facilities for the production of next-generation renewable fuels.

- the Sustainable Development Natural Gas Fund seeks to support technologies in the residential sector: small-scale affordable combined heat and power units, ultra-efficient water heaters, technologies that improve the efficiency of residential heating and/or cooling.

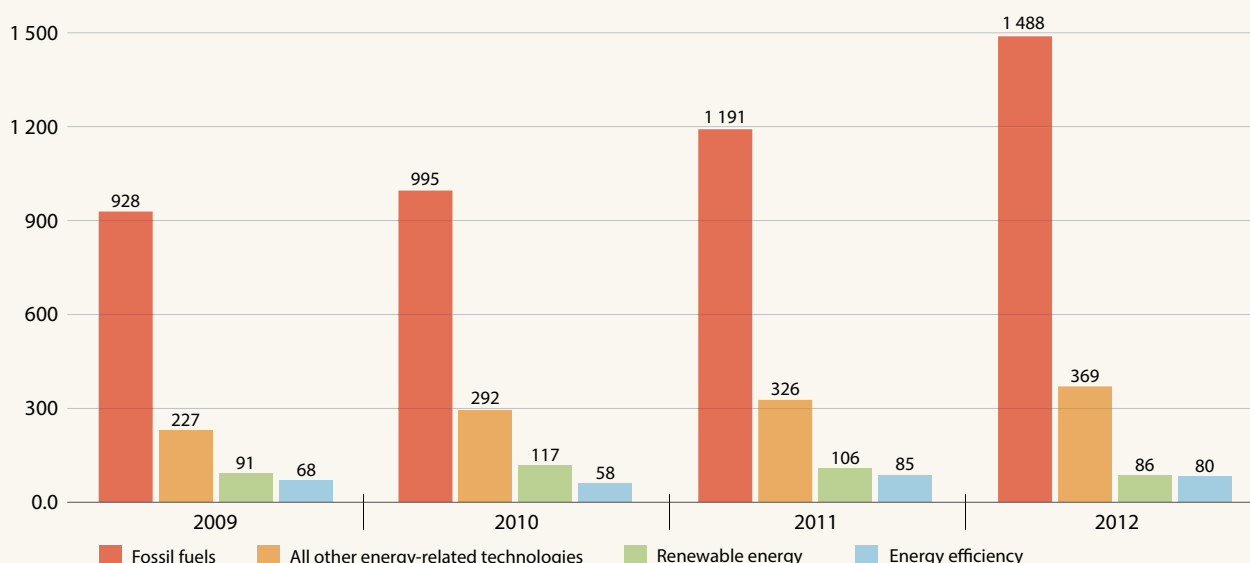
Another group dabbling in renewable energy is the National Research Council (NRC), Canada's largest public research organization. In retooling its mandate into that of a research and technology organization over the past year, it has launched a series of so-called flagship programmes which focus on research for industrial markets. The NRC's Algal Carbon Conversion Flagship aims to provide Canadian industry with solutions to divert CO₂ emissions into algal biomass, which could then be processed into biofuels and other marketable products.

In 2013, the Harper government abolished its sole source of independent, external advice on sustainable development issues (including energy), the National Roundtable on the Environment and the Economy. This agency had a mandate to raise awareness among Canadians and their government of the challenges of sustainable development. In over 25 years, it had released dozens of reports on priority issues.

Other groups have produced numerous reports on clean energy. Among these is the Council of Canadian Academies, which responds to federal requests for scientific assessments required for public policy input (among other clients). A 2013 report addresses how new and existing technologies can be used to reduce the environmental footprint of oil (tar) sands development on air, water and land. In 2014, the Council of

Figure 4.7: Canadian expenditure on energy-related industrial R&D, 2009–2012

By area of technology, in millions of current CAN\$



Source: Statistics Canada, August 2014

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Canadian Academies also published a report written by an expert panel on the state of knowledge concerning the potential environmental impact from the exploration, extraction and development of Canada's shale gas resources (CCA, 2014a).¹³

Lastly, the Canadian Academy of Engineering has produced an analytical report of note on progress regarding various renewable energy options for Canada. Bowman and Albion (2010) concluded that a Canadian network had been established in bio-energy but could find no evidence of a plan to organize, fund and undertake demonstration projects for the most promising bioenergy applications. In respect of other Canadian energy opportunities, the academy noted that:

13. In 2006, the CCA had been asked to address the challenge of safely extracting gas from gas hydrates. Its report cited estimates suggesting that the total amount of natural gas bound in hydrate form may exceed all conventional gas resources – coal, oil and natural gas combined. It also identified challenges linked to extracting gas from the hydrates, including the potential impact on environmental policy and unknown effects on communities (CCA, 2006).

- advances in solar heating and power were now ready for wider application and that this could provide the basis for a rejuvenated Canadian manufacturing sector;
- wind power in Canada had expanded to close to 4 000 MW but progress towards grid integration, load forecasting, cost-effective electrical energy storage and the development of a Canadian design and fabrication capability remained limited;
- projects were in place to upgrade tar sands bitumen to higher value products but this would require major funding to move from the pilot stage to the field demonstration stage; and that
- hydrogen was an active research area that counted several demonstration projects related to British Columbia's Hydrogen Highway and an inter-university programme on the production of hydrogen through the thermo-chemical splitting of water.

Box 4.2: Genomics is a growing priority for Canada

Genome Canada is Canada's principal player in genomics research. Constituted as a non-profit corporation in 2000, it works as a co-operative and collaborative network, with six* regional genome centres, combining national leadership with the ability to respond to regional and local needs and priorities. This has allowed regional expertise to be translated into applications for those who can use them most effectively.

For instance, livestock, energy and crop improvement projects are located in Alberta, Saskatchewan and Manitoba, aquaculture and wild fisheries in the coastal regions, forestry in western Canada and Quebec and human health research predominantly in Atlantic Canada, Ontario, Quebec, and British Columbia. With the financial support of the Canadian government for over almost 15 years (totalling CAN\$ 1.2 billion) and co-funding from provinces, industry, national and international funding

* Genome British Columbia, Genome Alberta, Genome Prairie, Ontario Genomics Institute, Genome Quebec and Genome Atlantic

organizations, philanthropists, Canadian institutions and others, Genome Canada and the regional Genome Centres have together invested over CAN\$ 2 billion in genomics research, across all provinces in all life science sectors.

Genome Canada has also invested CAN\$ 15.5 million in a new Genomics Innovation Network. The network is comprised of ten 'nodes,' each of which receives core operational funding from Genome Canada, with matching funds from various public and private sector partners. The Genomics Innovation Network allows innovation centres across Canada to collaborate and harness their collective strength to advancing genomics research. Each node provides Canadian and international researchers with access to the leading-edge technologies required to conduct research in genomics, metabolomics, proteomics and related areas.

Within the federal government, there is also a capacity for genomics research. The ongoing value of government-performed genomics research received an endorsement in 2014 with the

renewal of the Genomics Research and Development Initiative (GRDI) and funding of CAN\$ 100 million over five years.

With this latest slice of funding, GRDI has brought in the Canadian Food Inspection Agency as a full member and is allocating greater resources to interdepartmental projects. Discussions were initiated with Genome Canada in 2011 to find a mechanism for formal collaboration.

Participating departments and agencies are also finding that GRDI funding is attracting resources from other sources. In its annual report for financial year 2012–2013, the initiative reported that its investment that year of CAN\$ 19.9 million had leveraged a further CAN\$ 31.9 million for an annual total of CAN\$ 51.8 million. The National Research Council had achieved the highest leverage, using its initial endowment of CAN\$ 4.8 million to attract an additional CAN\$ 10.1 million.

Source: compiled by author

...but clean energy remains the poor relation

According to Statistics Canada, energy-related R&D rose by 18.4% from 2011 to CAN\$ 2.0 billion in 2012, mostly as a result of increases in R&D expenditure on fossil-fuel technologies. R&D spending on the latter was concentrated in oil (tar) sands and heavy crude oil technologies, up 53.6% to CAN\$ 886 million, and in crude oil and natural gas technologies, almost unchanged at CAN\$ 554 million.

By contrast, R&D spending on energy-efficient technologies fell by 5.9% to CAN\$ 80 million and spending on renewable energy technologies fell by 18.9% to CAN\$ 86 million between 2011 and 2012 (Figure 4.7).

In short, whereas green energy and clean-tech are receiving some attention from the private sector and policy circles, they are no match for the scale of support and advocacy behind conventional sources, including tar sands. Moreover, with the global decline in oil prices since mid-2014, the overall strategy of investing capital (political and otherwise) in this one sector has now put Canada's economic health in jeopardy.

Although energy questions currently consume much of the policy and incentive focus for R&D support, other areas have also received some attention in recent years. Genomics, for instance, has risen to the top of the priority list for support (Box 4.2). This is hardly surprising, since Canada is particularly prolific in clinical medicine and biomedical research (Figure 4.5).

POLICY ISSUES IN HIGHER EDUCATION

The talent and skills conundrum

A national debate is under way as to what kinds of skills, training and talent Canada needs for the 21st century. This is not a new debate but it has taken on a fresh urgency with the accumulation of warning signs, particularly as regards higher education. For one thing, Canada is slipping in higher education rankings. According to the *World Competitiveness Report* published by the World Economic Forum in 2014, Canada ranks second in the world for primary school enrolment, yet only 23rd for secondary enrolment and 45th for post-secondary enrolment.

A report from the government's own Science, Technology and Innovation Council has commented on the need to address the talent base. Canada's share of human resources in S&T in the manufacturing labour force amounts to only 11.5% – among the lowest in OECD countries. Canada's higher education investment in R&D (HERD) as a proportion of GDP has fluctuated, declining to

0.65% in 2013. With this decline, Canada's rank among 41 economies has dropped from fourth in 2008 and third in 2006 to ninth.

Meanwhile, reports from both the Council of Canadian Academies and the Science, Technology and Innovation Council (STIC) have pointed to shifts in Canada's position with respect to research excellence (STIC, 2012; CCA, 2013a). They have noted a need for improvement in two strategic areas: the production of doctoral graduates per 100 000 population and higher education expenditure on R&D as a share of GDP (Figures 4.8 and 4.9).

This public policy challenge stems largely from the fact that Canada has no central authority responsible for education, no ministry of education. Rather, the responsibility for training and education tends to fall to provincial governments, with the exception of periodic attempts by the central government to weigh in and provide incentives and other forms of moral suasion.

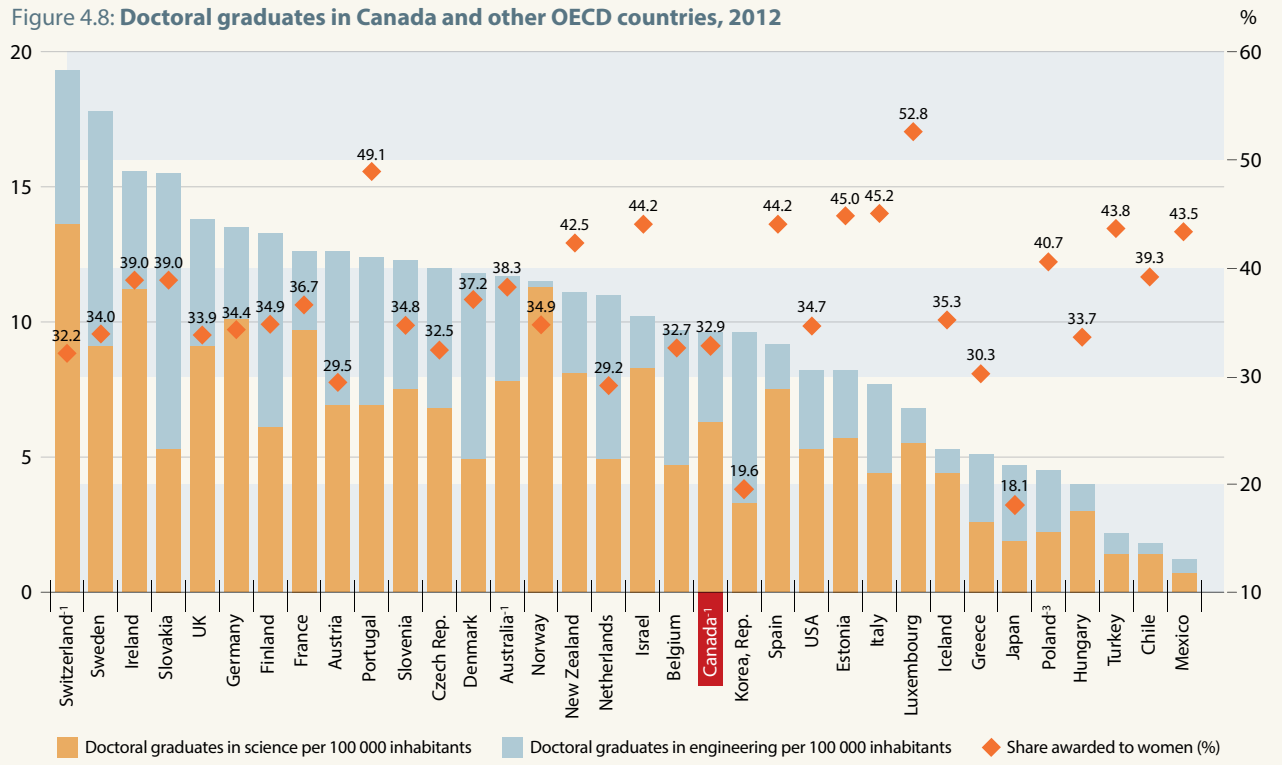
While education remains almost exclusively a provincial matter, responsibility for R&D is undefined constitutionally. As a result, different levels of government intervene with various policy instruments, leading to varying outcomes.

This makes for a complex web of actors and recipients, often with unco-ordinated leadership, not to mention a certain confusion.

To be sure, the focus on job creation has increased somewhat, with assessments currently under way to examine the country's educational assets. For instance, the Council of Canadian Academies has been called in to assess how well-prepared Canada is to meet future requirements for skills in science, technology, engineering and mathematics (STEM). The council's assessment examined the role of STEM skills in fostering productivity, innovation and growth in a rapidly changing demographic, economic, and technological environment, as well as the extent and nature of the global market for STEM skills. It also assessed how STEM skills were likely to evolve, which skills were likely to be most important for Canada and how well Canada was positioned to meet future needs in terms of STEM skills through education and international migration.

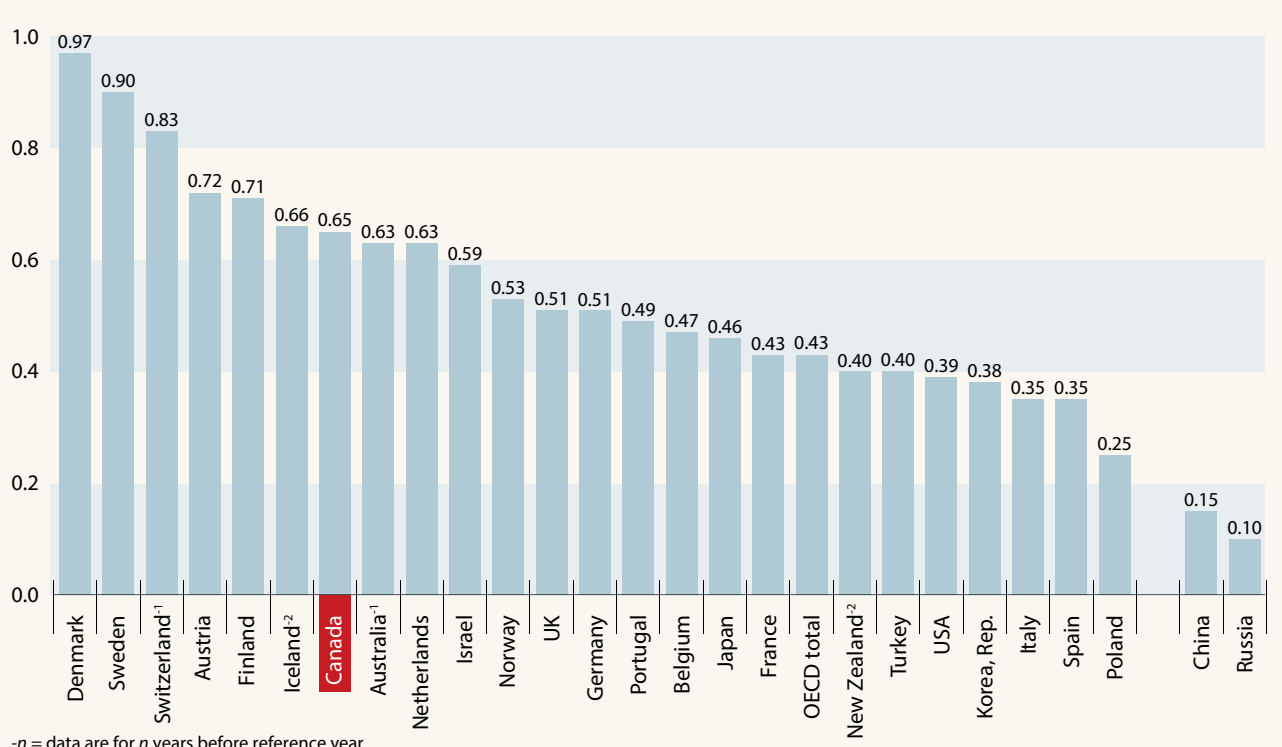
There are also some new incentives to encourage foreign scholars to come to Canada and, reciprocally, to increase the engagement of Canadian students internationally, but this tends to be piecemeal in approach. In addition, some adjustments have been made to Canada's immigration policy, in part to attract new talent and skills.

Figure 4.8: Doctoral graduates in Canada and other OECD countries, 2012



-n = data are for n years before reference year
 Source: UNESCO Institute for Statistics, April 2015

Figure 4.9: Spending on R&D in higher education in Canada and other OECD countries as a share of GDP, 2013 (%)
 Non-OECD countries are given for comparison



-n = data are for n years before reference year
 Source: OECD (2015) Main Science and Technology Indicators

The future of education will be international

In 2011, the federal government commissioned an expert panel to examine the question of international education. The Advisory Panel on Canada's International Education Strategy was led by Amit Chakma, President and Vice-Chancellor of the University of Western Ontario. The panel was asked to make recommendations regarding how to maximize economic opportunities for Canada in the field of international education, including greater engagement with emerging key markets, a focus on attracting the brightest international students, encouraging Canadians to study abroad, expanding the delivery of Canadian education services abroad and building bigger partnerships between Canadian and foreign institutions.

The report was commissioned in the context of the federal government's *Global Commerce Strategy (2007–2013)*, the precursor to its *Global Markets Action Plan*. Among the expert panel's final recommendations in August 2012 were to:

- double the number of international students choosing Canada from 239 131 to 450 000 by 2022 without displacing any domestic students;
- create 50 000 opportunities per year for Canadian students to go abroad for study and cultural exchanges;
- introduce 8 000 new scholarships for international students, co-funded by the Canadian federal and provincial governments;
- improve education visa processing to provide consistent and timely processing for high-quality candidates;
- target promotional efforts towards priority markets, including China, India, Brazil, the Middle East and North Africa, while maintaining traditional markets like the USA, France and UK, and develop Canada's education 'brand,' to be used by all partners in priority markets;
- improve linkages and collaboration between Canadian and international educational institutions and research institutes and;
- entrench a pan-Canadian approach in the international education sector with all key stakeholders and align activities to advance shared objectives better.

Box 4.3: The Canadian public has a positive attitude towards science

A survey of Canada's science culture

In August 2014, the Council of Canadian Academies released an assessment of Canada's science culture, based on a survey of 2 004 Canadians.

The expert panel assessed gender imbalances in science, the participation of aboriginal communities and the influence of a bilingual culture on popular science, among other issues.

The survey revealed that Canadians had positive attitudes towards science and technology and few reservations about science, compared to citizens of other countries. Canadians also showed above-average levels of support for public funding of research, compared to other countries.

The report also revealed an extensive popular science culture in Canada, with over 700 programmes or organizations: museums, science weeks and festivals, science fairs, etc.

Here are the study's main findings:

- 93% of Canadians surveyed were moderately or very interested in scientific discoveries and technological developments; for this measure, Canada ranks 1st out of 33 countries for which data are available.
- Respondents who were younger, male, highly educated and/or had high incomes showed a greater interest in science; this is consistent with findings from other countries.
- About 42% of respondents exhibited sufficient knowledge to grasp basic concepts and understand general media coverage of scientific issues but less than half had sufficient knowledge to understand current public debates about issues involving science and technology.
- Canada ranks first among OECD countries for overall post-secondary educational attainment (diplomas and degrees) but only 20% of first university degrees are in the sciences and engineering.

- More than half (51%) of those who hold degrees in science, technology, engineering or mathematics are immigrants.

Testing public attitudes towards robots

In 2014, a team of academics in communication, multimedia and mechatronics decided to test whether robots could trust humans. Scientists from the Universities of Ryerson, McMaster and Toronto built a 'friendly' robot using artificial intelligence and technologies for speech recognition and processing. They then equipped Hitchbot (the hitchhiking robot) with a GPS and left it by the roadside on a summer's day, after publicizing the experiment. Would Canadian motorists pick Hitchbot up and carry the robot towards its ultimate destination 6 000 km distant? The experiment was a success, with motorists posting photos of themselves with Hitchbot on Facebook and other social media (see photo, p.106).

Source: CCA (2014b); for Hitchbot: press release

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In 2014, the government responded to several of the report's recommendations through the release of its *Comprehensive International Education Strategy*. For instance, the government assigned CAN\$ 5 million per year to addressing the first objective of doubling the number of students; it also highlighted the need to focus resources and efforts on priority markets aligned with Canada's *Global Markets Action Plan*, namely Brazil, China, India, Mexico, North Africa and the Middle East and Viet Nam.

In June 2014, two advocacy groups, the Council of Chief Executives and the Canadian International Council, argued in their joint report that one of the reasons why Canada – with 120 000 international students – trailed countries such as the UK (427 000) and Australia (almost 250 000) was the lack of a unified brand to promote itself (Simon, 2014).

Their report noted that Canada was the only developed country without a national ministry of education. Using 2011 UNESCO rankings of international students per country, the report underscored Canada's eighth place ranking. Its ability to attract students from China, the biggest source of foreign students, was dismal, it noted, at only 3.8%. The report proposed that Canada create a new organization to brand international education as being central to both domestic and foreign policy, which would be known as Education Canada.

Eight out of ten universities seek high-quality partnerships

Universities across Canada are taking a more strategic approach to internationalization. According to a recent survey, Canadian universities are deeply committed to internationalization. Fully 95% identify it as part of their strategic planning and 82% view it as one of their top five priorities; 89% of respondents say that the pace of internationalization on their campuses has accelerated (either greatly or somewhat) during the past three years (AUCC, 2014).

The commitment of universities to internationalization is also becoming more sophisticated. For example, the pursuit of high-quality partnerships is now a priority for 79% of institutions. Evaluation is also growing: today, 59% of Canadian universities track the implementation of their internationalization strategies within their quality assessment and assurance procedures and just over three-fifths assess their success in supporting international students.

The most common top priority for internationalization is undergraduate student recruitment, identified by 45% universities as being their highest priority and by 70% as figuring among their top five priorities. The next top-rated priorities are to pursue strategic partnerships with universities overseas and to expand international academic research collaboration.

With regard to Canadian education abroad, more than 80% of universities which responded to the survey offer a degree or certificate programme abroad with international partners and 97% offer opportunities for Canadian students to do academic coursework abroad. However, outbound student mobility remains low: just 3.1% of full-time undergraduates (about 25 000) had an international experience in 2012–2013 and only 2.6% had chalked up a for-credit experience abroad (up slightly from 2.2% in 2006). Cost and inflexible curricular or credit transfer policies are perceived as being major barriers to greater student participation.

Not surprisingly, China is overwhelmingly the top focus for almost all the efforts by Canadian universities to internationalize their institutions. China has become Canada's third-biggest partner in terms of joint scientific authorship (Figure 4.5).

As for Canadian students themselves, their preferred destinations for an overseas experience remain the traditional English-speaking and major Western European nations, despite their universities' geographical focus on developing powers.

FOSTERING AN INNOVATION CULTURE

New programmes and a facelift for others

The federal budget of 2014 contains a major new funding programme called the Canada First Research Excellence Fund (CFREF). In announcing the federal strategy for STI in 2014, the prime minister also launched the competition for this new programme.

Pegged at CAN\$ 50 million for the first year (2015–2016), CFREF is designed to drive Canadian post-secondary institutions to excel globally in research areas that create long-term economic advantages for Canada. The fund joins programmes such as the Canada Excellence Research Chairs and the Canada Research Chairs. Once implemented, it will presumably contribute significantly to research across all disciplines. CFREF will be available to all post-secondary institutions on a competitive, peer-reviewed basis.

The fund will be administered by the Social Sciences and Humanities Research Council of Canada, in collaboration with the Natural Sciences and Engineering Research Council of Canada and the Canadian Institutes of Health Research. These three funding councils collaborate trilaterally on issues such as open access. Each is currently undergoing a transformation to centre it more on its core mission.

The Canadian Institutes of Health Research have undergone a retooling of their own business model. Meanwhile, the Natural Sciences and Engineering Research Council has launched a

consultation on its strategic plan to 2020, which will lay greater emphasis on developing a science culture, global outreach and discovery (basic) research.

For its part, the Social Sciences and Humanities Research Council is examining the vital role of social sciences and humanities in knowledge production and their contribution to future social issues, including challenges such as:

- What new ways of learning will Canadians need to adopt at university, in particular, to thrive in an evolving society and labour market?
- What effects will the quest for energy and natural resources have on our society and our position on the world stage?
- How are the experiences and aspirations of Aboriginal Peoples in Canada essential to building a successful shared future?
- What might the implications be for Canada of a global peak population?
- How can emerging technologies be leveraged to benefit Canadians?
- What knowledge will Canada need to thrive in an interconnected, evolving global landscape?

Last but not least, it is worth noting that another unique education cum training programme continues to receive federal support. The federal government announced in its 2013 and 2014 budgets a combined CAN\$ 21 million investment in industrial research and training for postdoctoral fellows through a former programme of the Networks of Centres of Excellence¹⁴ known as Mitacs. Mitacs co-ordinates collaborative industry–university research projects with human capital development. Since 1999, Mitacs has been promoting academic–industrial R&D while supporting the development of future innovation leaders. In particular, Mitacs:

- helps companies identify their innovation needs and matches them with academic expertise;
- fosters cutting edge research tied to commercial outcomes;

¹⁴ Since their inception in 1989, the Networks of Centres of Excellence have administered national funding programmes on behalf of the Natural Sciences and Engineering Research Council, Canadian Institutes of Health Research and Social Sciences and Humanities Research Council of Canada, in partnership with Industry Canada and Health Canada. These programmes support large-scale, multidisciplinary collaboration between universities, industry, government and non-profit organizations. The programme has expanded over the years to comprise: 16 NCEs; 23 Centres of Excellence for the Commercialization of Research and 5 Business-led Networks of Centres of Excellence.

- builds international research networks, creating innovation leaders in Canada and abroad; and
- provides professional and entrepreneurship skills training for graduate students, so that they have the tools to meet emerging innovation needs.

Business-led Networks of Centres of Excellence

The Business-led Networks of Centres of Excellence (NCE) programme also fosters an innovation culture. Led by a non-profit consortium of industrial partners, each of these large-scale collaborative research networks focuses on specific challenges identified by a given industrial sector. The programme's partnership model places academic and private-sector partners on an equal footing; it allows networks to fund private sector partners directly so they can conduct research at their own facilities.

The programme was created in 2007 and made permanent in the 2012 federal budget, with annual funding of CAN\$ 12 million. It proposes funding on a competitive basis. Matching requirements mean that at least half of each network's research costs are paid by the partners. In 2014, the newly formed Refined Manufacturing Acceleration Process (ReMAP) network was awarded CAN\$ 7.7 million over five years through this programme, for instance, to develop technologies of benefit to the electronics sector. The research partnership involves academics, research organizations and a wide range of companies.

There is some debate as to whether the current mix of NCEs should not be more closely aligned with the federal government's most recent STI priorities, as outlined in its 2014 strategy. As Table 4.5 illustrates, the match is not evenly distributed across the five redefined priority areas (Watters, 2014).

Table 4.5: Networks of centres of excellence in Canada by sector, 2014

	Number	Share of total (%)	Share of total funding (%)	Total (CAN\$ millions)
ICTs	6	14	8	81.7
Natural resources	6	14	8	83.3
Manufacturing/Engineering	2	5	9	88.9
Cross-sectorial	4	9	8	76.9
Environment	5	11	24	235.1
Health and life sciences	25	48	42	420.8
Total	44	100	100	986.6

Source: Watters (2014)

CONCLUSION

Science powers commerce (but not only)

The Canadian research landscape continues to evolve across the country along with a somewhat muted global reach. Research partnerships and science diplomacy are increasingly tied to trade and commercial opportunities. The international development envelope is now embedded in one large department, since the elimination of the Canadian International Development Agency.

The research system has become more complex, with a diversity of programmes that have often been established unilaterally at the federal level, prompting corresponding responses at provincial levels. There has been a marked increase in policy guidance, with a view to setting research priorities to suit the political agenda of the incumbent government. Several areas continue to attract high-level policy attention, including northern education and research infrastructure, along with global health – especially maternal and newborn child health – through a multi-million dollar Grand Challenges Canada programme that catalyses partnerships and support using an integrated approach to innovation.

A key consideration has been the impact of austerity budgets in Canada, which limit the ability of public policy to make up for shortfalls in research funding overall, in a context of rising enrolments and diminishing success rates for research grants. This trend is particularly visible in basic research – also known as discovery research – where the returns are often seen to be long-term and thus stretching well beyond the term of individual government mandates. As a result, there has been a tendency to focus support on more applied research, or that which can be shown to have a commercial outcome. Perhaps the best expression of this is Prime Minister Harper's mantra that 'science powers commerce.' That is true. Science does power commerce – but not only. The current drive to steer so-called public good science (e.g. regulatory, environmental) towards business and commercial outcomes reflects a focus on short term goals and a rapid return on investment in research that is short-sighted. This trend suggests that federal funding for basic research and public good science may continue to decline in Canada, even though the business world itself relies on the generation of new knowledge to nurture the commercial ideas of tomorrow.

With the federal election looming in late 2015, political parties have been jockeying for attention on issues that matter to the Canadian public. STI will receive some attention from all political parties in the run-up to the election. The official opposition New Democratic Party, for example, has outlined plans to introduce a Parliamentary Science Officer with a mandate to provide policy-makers with sound information and expert advice on all scientific matters of

relevance. The Liberal Party has introduced a draft bill to re-instate the long-form census at Statistics Canada, eliminated by the Conservative government. However, history has shown that such endeavours turn out to be marginal at best, since science and technology are rarely at the centre of decision-making and budgetary outlays. Rather, they essentially receive 'CPA' – continuous partial attention – from all governments.

Canada will be celebrating its 150th birthday in 2017. If the country is serious about reinvigorating its knowledge culture and positioning itself as a world leader via STI, a more concerted and co-ordinated national effort will be required with demonstrated leadership from all stakeholders. An opportunity exists to seize the day – but Canada must engage all stakeholders in an open and transparent fashion.

KEY TARGETS FOR CANADA

- Double the number of international students choosing Canada to 450 000 by 2022, without displacing any domestic students;
- Raise the share of electricity generated in Canada from non-greenhouse gas emitting sources to 90%, including nuclear energy, clean coal, wind and hydroelectricity;
- Cut CAN\$ 2.6 billion from 10 federal science-based departments and agencies between 2013 and 2016.

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