Policy Brief

The Forum Presents:

Science and Technology in Canada

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Introduction

The last several decades have witnessed mounting concern by academe, government, business and the public about the state of Canadian science, technology and innovation (STI)[1]. While some concerns are long-standing, the last decade has seen an unprecedented public airing of concerns, voiced by a wide range of stakeholders.

There are two broad *input* determinants of STI enterprise. One is STI *investment* including both investment in STI capacity (i.e. STEM[2] and STEAM education; college and university training, etc.) and investment in research and development (R&D) activities. These investments can be made by governments, business, universities and colleges, and civil society.

The second is STI *culture*. This determinant captures *interest in*, *understanding of*, *attitudes about*, and *engagement with* science and technology by a wide range of stakeholders, from government through business to the public at large. Combined, these four elements (interest, understanding, attitudes and engagement) reflect the importance different stakeholders place on scientific R&D and technology innovation and, as a consequence, their willingness to invest in and support the STI enterprise.

What is the state of Canadian investment in scientific research and development overall?

One standard measure employed by the Organization for Economic Cooperation and Development (OECD) is the % of annual Gross Domestic Product (GDP) expended on research and development. Over the first half of the last decade, Canada's Gross Domestic Expenditure on Research and Development (GERD[3]) was stable at about 2% of GDP, well below the G7 average of 2.15%, but above the OECD average of 2.10%. Since 2006, it has declined steadily, and in 2013 - the last year for which systematic comparative data are available - stood at 1.62% of GDP. During the same period, many OECD and G7 countries increased spending on R&D[4]: in 2013, OECD countries spent, on average, 2.36% of GDP on research and development. As a consequence, in 2013, Canada ranked 24th in GERD intensity (spending per GDP), down from 16th in 2006[5].

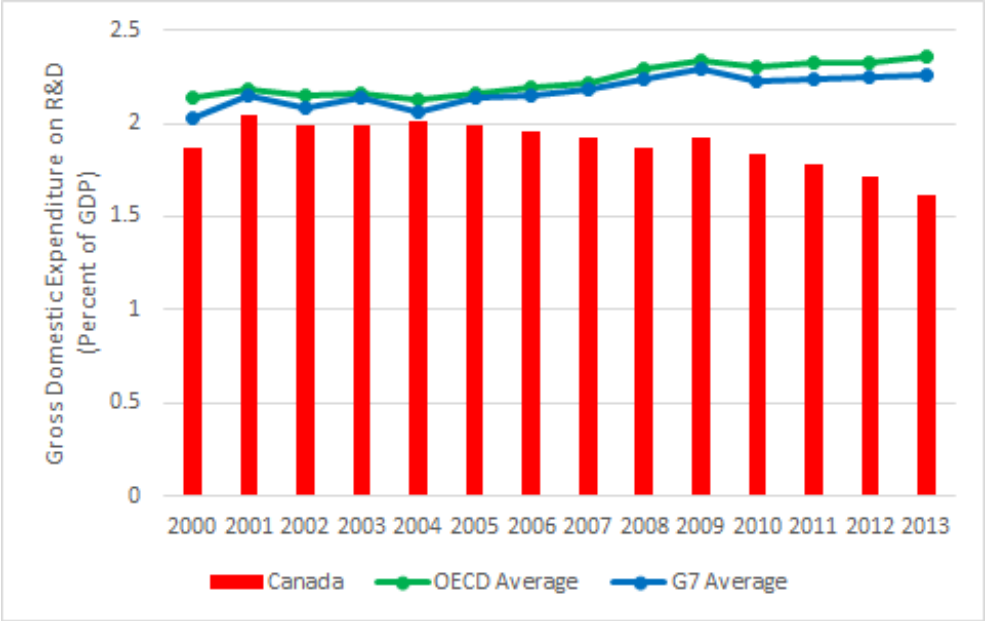

Fig. 1. Canadian GERD intensity from 2000-2013 compared to the OECD and G7 average.

The short answer, then, is that Canada's overall investment in scientific R&D is underwhelming, at least with respect to international comparators.

How about the state of Canadian science culture? A recent report by the Canadian Council of Academies[6] concludes that, in comparison to other countries, Canadians have generally positive attitudes towards, and show a high level of engagement with, science and technology. Canadians also show comparatively little concern about the potentially disruptive effects of science and technology, ranking 1st of 17 industrialized comparator countries[7]. Finally, Canadians appear to have a comparatively high level of understanding of basic scientific principles, with the level of public understanding of science increasing since 1989[8].

All of this suggests that the state of science culture in Canada, at least among the public, is reasonably healthy. But there are worrying signs. Canada's PISA (Programme for International Student Assessment) scores in science and mathematics have declined since 2006; the result is that Canada's standing in mathematics has fallen from 3rd to 10th, and in science from 7th to 14th [9]. In 2013, only 20% of first university degrees in Canada were in STEM fields, 19th out of 29 comparator countries[10].

Against this backdrop, concerns about the state of Canadian STI fall into three broad categories:

- Federal investment in, and capacity for, scientific research and development, especially with respect to public interest science generally, and intramural public interest science more specifically

- Business performance in innovation generally, and more specifically, investment by business in science and technology research and development; and

- The state of science culture both within and outside government.

By virtue of its regulatory and statutory authority and/or purchasing power, the federal government has the potential to address all three concerns. But it cannot, and indeed, should not, do it alone. Reinvigorating the Canadian STI enterprise requires, first and foremost, restoring and sustaining the health of the Canadian STI ecosystem with all of its constituent elements and actors, from investors (angels, venture capitalists, pension funds and governments) to producers (science and technology institutions, including universities and colleges; business; governments and civil society) to consumers (business, industry, government, civil society and the general public).

INVESTMENT IN SCIENCE AND TECHNOLOGY

Regional science and technology (S&T) development

Background: In March 1987, federal, provincial and territorial leaders signed the first (and only, thus far) *National Science and Technology Policy*[xi](NSTP) that included six major objectives[xii]. The NSTP was the culmination of an extensive three-year process of consultation with provincial and territorial governments as well as the full range of science R&D stakeholders. Since that time, Canada has seen a series of *federal* science and technology strategies: *Innovaction* in 1987[xiii]; *Science and Technology for the New Century* in *1996*[xiv]; *Mobilizing Science and Technology to Canada's Advantage*[xv] in 2007; and *Seizing Canada's Moment*[xvi] in 2014.

Unlike its successors, the 1987 NTSP included a major focus on bilateral federal-provincial/territorial agreements. These Economic and Regional Development Agreements (ERDAs) were in effect between 1984 and 1994, and formed the basis for almost a hundred subsidiary agreements, a number of which focused specifically on joint federal-provincial investments in science and technology[xvii]. On the elimination of the federal Department of Regional Industrial Expansion (DRIE), federal regional economic development was transferred to regional economic development agencies, five of which are still in place today.

The issue: Since 1996, federal science and technology strategies have focused principally on ways and means by which the federal government might directly influence Canadian S&T, either through direct investment, through its purchasing power, or through regulatory and financial instruments (e.g. tax credits) that fall within its jurisdictional powers. None of these strategies, most notably the 2007 and 2014 incarnations, have made a serious attempt to engage provincial, territorial, First Nations or municipal governments in developing regional S&T strategies or fostering healthy S&T ecosystems at the regional level.

Recommendation:

Develop and implement a new *national* science and technology strategy based upon a set of regional, multilateral S&T agreements, negotiated through the existing federal development agencies. Such agreements would have, as their primary objective, the restoration of the health of *regional* S&T ecosystems, and should be based on open consultations with S&T producers and consumers, including provincial, territorial, First Nations and municipal governments; academe; civil society and the business (including investment) sector. In particular, they would provide vehicles for the identification of regional S&T priorities, as well as the design and delivery of government support programs to S&T producers, including business, colleges and universities, and civil society.

Declining federal investment in scientific research and development

Background: The federal government is a major contributor to scientific research and development, but directly through investments in intramural science and technology development, and indirectly through extramural investment in research in universities and colleges and joint S&T enterprises with business.

Over the past several decades, the federal contribution to GERD has declined. In 1970, federal investment accounted for more than 30% of the total annual S&T expenditures; by 2011, it had shrunk to 9%[xviii]. Total S&T spending by the federal government has declined, from a high of $12.04B (CAN) in 2009-2010 to $10.6B in FY 2014-2015 (Fig 2)[xix]. On the other hand, most recent estimates show a projected increase in S&T spending by the federal government of 2.1% overall in FY 2015-2016[xx].

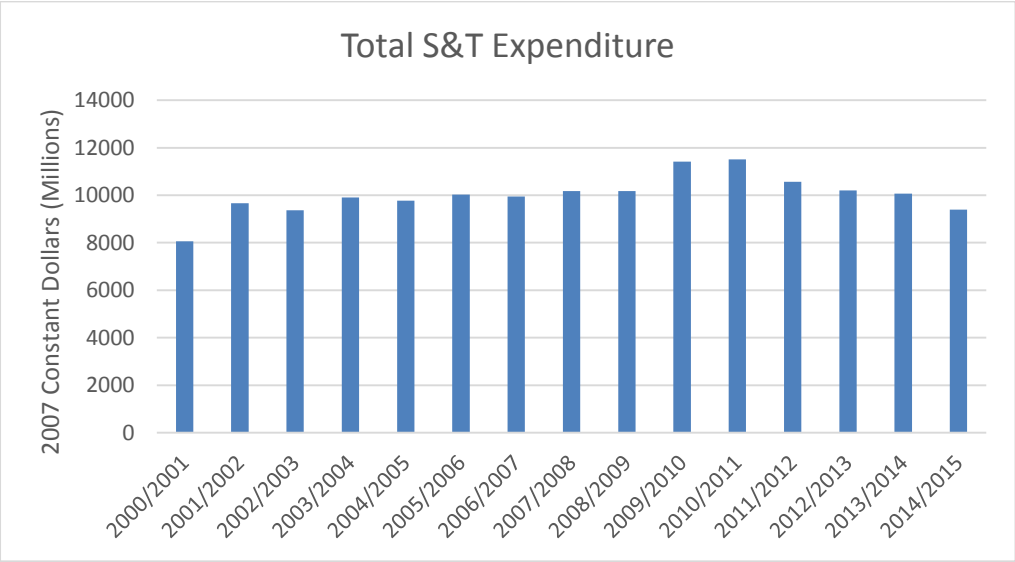

Fig. 2. Federal expenditures on science and technology, 2000/2001-2014/2015, in constant 2007 dollars.

Embedded within this overall trend of declining federal investment are two particularly worrying trends. One concerns intramural S&T spending, that is, expenditures on science and technology spent *within* federal departments and agencies. While some of these expenditures are allocated to basic research and technology development, the lion's share goes to the science that supports federal statutory, regulatory and policy decision-making. From FY 2000/2001 to FY 2010/11, intramural S&T spending increased from $4.04 B to $6.06B, but declined to $5.42B in 2015[xxi]. These reductions have resulted in the closing of a large number of federal science units and programs[xxii]. In a recent report, the Professional Institute of the Public Service estimated that between 2008 and 2013, $596

million was cut from science and technology at federal departments and agencies, eliminating the equivalent of 2,141 full-time positions[xxiii].

A second trend concerns federal investment in research conducted at colleges and universities. Federal funding to research and development activities in higher education (so called HERD) sector was stable at about $0.8B during the 1990s, and rapidly increased from the late 1990s to $3.2B in 2011, since when it has increased very slightly[xxiv]. Although absolute investment in higher education research and development (HERD) has increased, between 2006 and 2013, Canada's position with respect to HERD intensity (HERD per GDP) has deteriorated from 3rd to 8th position globally, principally as a result of greater investments in HERD by competitor nations[xxv].

The issue: There is widespread concern that historical and ongoing reductions in federal investment in science and technology has compromised the ability of the federal government to sustain its core S&T functions: supporting statutory, regulatory and policy decision-making and standards; producing products and services that enhance public welfare (e.g. health, safety, security, etc.); providing anticipatory/adaptive knowledge and technologies to respond quickly to national priorities; and facilitating technology innovation[xxvi].

Recommendations:

- In consultation with other elements of the Canadian S&T ecosystem (other levels of governments, universities and colleges, business and civil society), undertake a thorough assessment and analysis of the resources required to sustain critical federal S&T functions at a high level, including especially internal S&T capacity[xxvii].
- Increase federal investment in higher education research and development to a level sufficient to keep pace with other countries[xxviii].

Low and declining investment by business in research and development

Background: Business is an important component of the S&T ecosystem, acting both as a science and technology producer and consumer. As a producer, one performance indicator is how much business invests in research and development.

On this metric – as on several others – Canadian business performance is poor. Business enterprise research and development per unit GDP (BERD intensity) has been dropping steadily, from 1.18% in 2005 to 0.82% in 2013 – half the OECD average (Fig. 4)[xxix]. A recent report by the Conference Board of Canada gave Canada a "D" for business investment in research and development, ranking it 15th of 16 comparator countries[xxx]. Another recent report by the Science, Technology and Innovation Council (STIC) ranked Canada 26th among international competitors, with BERD intensity at 36 percent of the

threshold of the top five performers[xxxi]. From 2007 to 2015, Canada's overall business investment in R&D dropped by over $1 billion[xxxii].

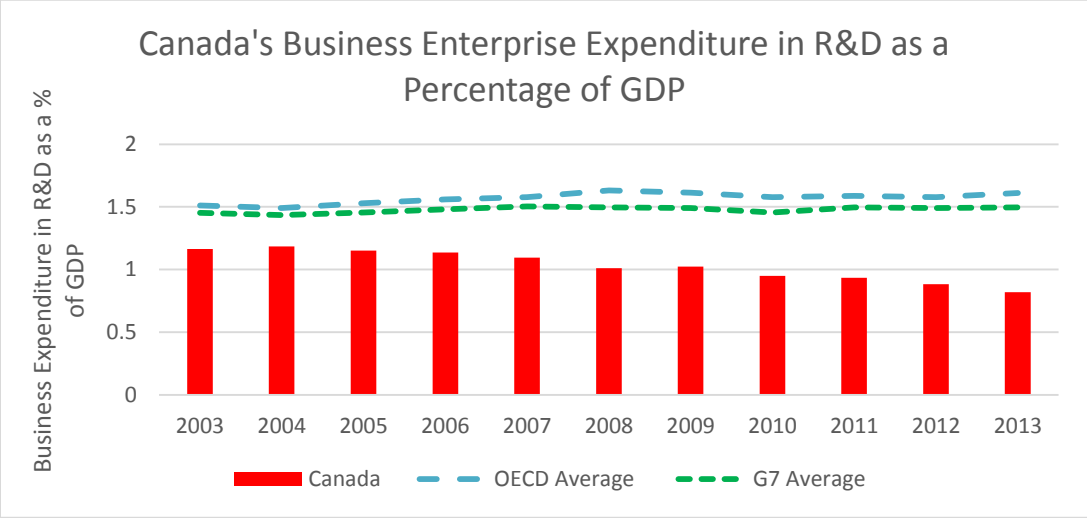

Fig. 4. Canadian business enterprise research and development as a percentage of GDP (BERD intensity), 2003-2013.

Canada's industrial/business R&D performance has been underwhelming for decades[xxxiii]. But its continued deterioration is especially problematic now: as the Conference Board points out, the Canadian economy is at the point where the risks of *not* investing in research and development outweigh the risks of doing so.

The issue: In part at least, Canada's comparatively poor productivity is a result of lacklustre business R&D performance. The past decades have seen a number of attempts by the federal government to stimulate business investment in R&D, most recently Venture Capital Action Plan that includes CAN$ 400 million in new capital over the next 7–10 years to encourage private investment in the form of venture capital funds, and the Canada Accelerator and Incubator

Program that provides grants of up to CAN$ 5 million annually to top business accelerators and incubators. Yet despite a sequence of federal strategies, business investment in

research and development continues to decline, and Canada continues to loose ground to international competitors[xxxiv].

Recommendations:

- Shift federal support for business towards direct funding, strategically targeting large companies engaged in high risk, high reward R&D and high-growth by small or medium sized enterprises (SMEs)[xxxv].
- Examine ways by which financial risks born by angel, VC or other investors may be mitigated or offset. Such vehicles might include non-refundable tax offsets or capital gains allowances for early stage investment.
- Examine existing insolvency laws to determine the extent to which they reduce risk tolerance for failure, especially by SMEs[xxxvi].
- Examine ways to revise federal government tendering and procurement policies so as to both provide markets for mature technologies and encourage development of new technologies[xxxvii].

Allocation of federal funding to basic versus applied versus commercialization R&D

Background: Scientific research and development ranges from basic or fundamental research, concerned essentially with understanding how nature works, to applied research and technology commercialization, concerned with bringing new technologies to market. A perennial issue is the extent to which scarce federal resources for science and technology ought to be allocated to different parts of the R&D spectrum.

The issue is a contentious one. On the one hand, everyone agrees that every commercial technology has its origins in fundamental research. Most would also agree that some of the core functions of federal S&T – for example, sustaining the health of both Canadians and the environments in which they live - depend on investment in fundamental research. On the other hand, better alignment of federal research priorities with the needs of business and industry is more likely to enhance business innovation and productivity.

In Canada, the last decade or so has seen a marked shift of federal investment away from basic scientific research. Following recommendations in the Jenkins report[xxxviii] , the core mission of the National Resource Council (NRC) was rewritten to focus on research of direct relevance to industry[xxxix], with only 20% of the annual budget, being allocated to basic research[xl]. More recently, the Canada First Research Excellence Fund, created in 2015, will provide $200 million annually for global research projects that are aligned with the federal science, technology and innovation priority research areas and demonstrate 'long-term economic advantages for Canada'.

The Natural Sciences and Engineering Research Council's (NSERC) Discovery program, which funds the majority of basic research in the natural sciences and

engineering has witnessed a 16% reduction in inflation-adjusted dollars from 2006 to 2013, coincident with a 167% increase in funding for NSERC's innovation program (Fig. 5). In the same time period, success rates for tri-council (NSERC, SSHRC, and CIHR) open research grants that serve as the main source of basic research funding have dropped from 70% to 59% NSERC 33% to 27% at SSHRC, and from 28% to 9% at CIHR[xli].

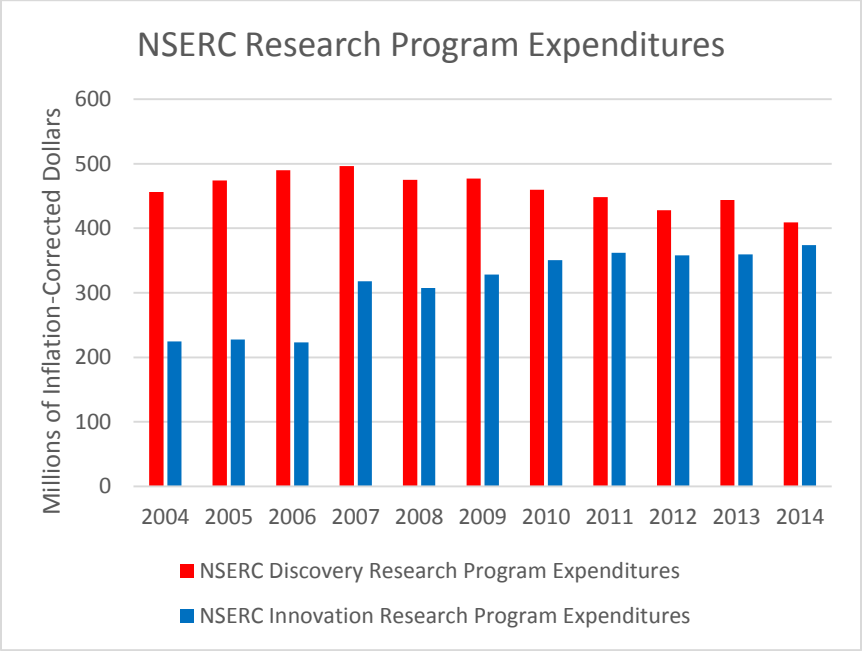

Fig. 5. Changes in allocation to basic (Discovery Research) versus applied/commercialization research (Innovation Research) at the Natural Science and Engineering Research Council of Canada, 2004-2014. NSERC's Discovery grant program supports research programs with long-term goals that advance knowledge in all fields of science and engineering. NSERC's Innovation grants support universities and colleges working with industry partners. Innovation research also includes support for technology transfer in specific government-defined sectors, with some programs requiring matched funding from industrial partners.

The issue: The shift away from federal funding of basic research to programs designed to support business and industry has been an ongoing concern among Canada's research community[xlii]. But there is also a need to provide strategic research support to facilitate business innovation, especially in sectors with large economic impacts.

Recommendation: In consultation with other elements of the Canadian S&T ecosystem (other levels of governments, universities and colleges, business and civil society), develop and implement principles and criteria for allocating federal support for fundamental versus applied versus commercialization (including technology prototyping, demonstration and deployment) research.

THE STATE OF FEDERAL GOVERNMENT SCIENCE CULTURE

Issue: Communication of federal science

Background: Probably no Canadian science issue has garnered more public attention over the last few years than policy decisions that have restricted the ability of federal government scientists to communicate their science with the media, the public, and with the scientific community outside government. The controversy has focused on two principle issues. First, to what extent is muzzling occurring?. Second if it is occurring, to what extent is it legal[xliii], justified by the federal code of values and ethics[xliv] and/or in the interests of the Canadian public?

There is by now a mountain of anecdotal evidence of communication constraints, both direct and indirect, being put on federal government scientists[xlv]. A 2013 survey found that 90% of federal scientists feel they are impeded from communicating freely with the media about their work[xlvi]. Almost three quarters of federal scientists (71%) believe this has compromised Canada's ability to develop policy, law and programs that is well-informed by scientific evidence. In 2014, a report evaluating media communication policies awarded 12 of 14 federal science departments grades of C or lower for openness, timeliness and transparency. These evaluations were substantially lower than those assigned (using the same methodology and criteria) to analogous departments in the United States in a comparable study[xlvii].

The issue of the justifiability of such constraints is more controversial. Some view allegations of "muzzling" as simply reflecting a lack of understanding of the responsibilities of both ministers and public servants under the *Code of Values and Ethics for the Public Sector* (CVEPS)[xlviii]. For others, although there may be good reasons for government scientists to refrain from commenting publicly on government policy, impeding communication of scientific information undermines government credibility and impedes the ability of Canadians to make informed decisions[xlix].

Recommendation: As part of its election platform, the new federal government has committed to eliminating existing constraints on the communication of federal science, and has already taken action to do so[l]. It is further recommended that it:

- Establish an explicit, pan-department policy that not only protects but facilitates and encourages federal scientists to communicate their science to the media, to the public, and to the broader scientific community.

- Review protocols for external communication of science and technical information, including publishing of scientific and technical articles, conference presentations and the like, to ensure timely and efficient dissemination.

- Empower the proposed Chief Science Officer[li] to work with the Office of the Information Commissioner and Treasury Board to develop operational guidelines to ensure that public communication of scientific and technical information complies with the *Code of Values and Ethics for the Public Sector*.

Issue: Enhancing the role and use of scientific evidence in government decision-making

Background: The last decade has seen increasing public concern over what has been characterized as "decision-based evidence-making" by critics of the former administration[lii] and, more generally, a flight from evidence-based decision making. The latter has manifested itself in a number of well-known examples of contentious issues whereby policy, regulatory and statutory decisions have been rendered that appear to ignore, or be inconsistent with, the existing scientific evidence[liii]. In some particularly egregious examples, the state of the scientific evidence has been publicly misrepresented[liv].

Over the past decade, a number of reports have examined the state of evidence-informed decision-making in governments[lv] . The goal of achieving systematic evidence-informed decision-making throughout government requires that (a) protocols concerning how science advice is solicited and incorporated into policy processes be designed and implemented; (b) those who would give science advice (researchers, science advisors, etc.) adopt a set of "best practice" principles[lvi] to ensure that the advice so provided is of maximum usefulness; (c) those who would receive science advice (policy advisors, ministers and parliamentarians) have sufficient understating of scientific evidence and its limitations to make informed decisions; and (d) that all evidence considered and used in the decision-making process is made publicly available unless there are compelling reasons for doing otherwise.

In the Canadian context, two initiatives are particularly noteworthy. The 1999 report from the now-defunct Canadian Council of Science and Technology Advisors *Science Advice for Government Effectiveness* (SAGE) outlined six basic principles to ensure that

ministers have confidence that systematic evaluation of all relevant science was made in providing advice; that credible science advice is considered by decision makers; and that both the public and parliamentarians are confident that government is using science in the best interests of all Canadians[lvii]. More recently, the *Science Integrity Project* has proposed a set of four principles designed to enhance the role of science in government decision-making[lviii]. Similar principles have also been recently articulated by the Royal Society of Canada[lix]

The issue: Public trust is crucial to the functioning of democratic governments. In large measure, this trust depends upon the open and transparent use of evidence in government decision-making. Over the last decade, the apparent repudiation – or at least, indifferent application – of evidence-informed decision-making has not only eroded the federal government's scientific credibility, but undermined public trust and contributed to a chronic malaise among government scientists.

Recommendation: To enhance evidence-informed decision-making, the federal government should:

- Implement the principles for scientific integrity and science-informed decision-making developed by the Science Integrity Project and the Royal Society of Canada into *all* federal decision-making;
- Review, update and implement SAGE to produce a set of best practice principles and criteria for those who provide science advice (science advisors, broadly construed) so as to ensure the advice is timely and useful;
- Develop a simple set of tools that would allow parliamentarians and other decision-makers to understand and assess the scientific evidence underlying candidate statutory, regulatory or policy options.

Issue: Federal science advice

Background: Elected Members of Parliament have recently been appointed to the roles of Minister of Science and Minister of Innovation, Science and Economic Development. The former's mandate letter specifically charges the Minister with the creation of the position of a Chief Science Officer, who will "ensure that government science is fully available to the public, that scientists are able to speak freely about their work, and that scientific analyses are considered when the government makes decisions."[lx]

The office of the National Science Advisor (NSA) existed in Canada from 2004-2008, but was discontinued by the Conservative government after the formation of the Science, Technology and Innovation Council (STIC) in June 2007. The NSA advised the prime

minister directly for two years (2004-2006), but was directed in 2006 by the newly elected government to advise the Minister of Industry for the remainder of his tenure as CSA.

As pointed out in a recent white paper by the Royal Society of Canada, many countries now have CSAs or their equivalents. Though their mandate varies somewhat, all CSAs provide science advice to government on a broad range of science and technology issues, both domestic and international; provide guidance on the appropriate interpretation of scientific evidence and associated uncertainties; perform public outreach and communication on a range of S&T issues; and chair some sort of science and technology advisory committee (STAC).

The issue: Although the broad responsibilities of the Chief Science Officer have been been outlined in the mandate letter to the Minister of Science, a number of issues remain, including to whom the CSO should report; the core functions that should be sustained by the office.

Recommendations: That the Office of the Chief Science Officer (CSO)

- be established in a manner that provides full independence from the government of the day as well as protection from political influence.
- should report to both the Prime Minister and the House of Commons/Senate, with the nature of the reporting differing between the two;
- should chair or co-chair a reconstituted and reconfigured Science, Technology and Innovation Advisory Committee (STIAC) established under the authority of the Department of Science and/or the Department of Innovation, Science and Economic Development;
- should assist in, and report to Parliament on, progress in enhancing science culture within the federal government, including in particular (a) open data and open science communication initiatives; (b) implementing of science integrity principles and SAGE (see above);
- should provide parliamentarians with accurate and timely advice on science and technology policy and ensure that the legislative process is appropriately informed by scientific and technical evidence;
- should regularly communicate with the public to ensure that it is adequately informed about science and technology issues of national import[lxi].

[1] A recent comprehensive summary of the state of science in Canada current to 2013 is provided by P. Dufour in *UNESCO Science Report: Towards 2030*, *Ch.* 4, available at https://en.unesco.org/sites/default/files/usr15_canada.pdf

[2] STEM refers to education in Science, Technology, Engineering and Mathematics, usually (but not invariably) at the post-secondary level. Conventionally, STEM education was held to produce the human capital that drives innovation. Recent work on public perceptions of technology and the role of design and marketing in market adoption of new technologies has led some to argue that education in the Arts (broadly construed) is also important to achieving significant market penetration (hence, "STEAM").

[3] Gross Domestic Expenditures on Research and Development (GERD) refers to all monies expended for Research and Development (R & D) performed within the country in a given year. R&D funding may come from government, busines , private non-profit, higher education or foreign sources. Statistics Canada collects R&D data on four performing sectors: government, business enterprise, private non-profit and higher education.

[4] Data on national performance on a suite of S&T indicators are available from the Organization for Economic Cooperation and Development, available at http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB

[5] Science, Technology and Innovation Council (STIC) (2015), *Canada's Innovation Challenges and Opportunities, p. 23.* Available at *http://www.stic-csti.ca/eic/site/stic-csti.nsf/vwapj/STIC_1500_SON_Report_e_proof4.pdf/$FILE/STIC_1500_SON_Report_e_proof4.pdf* .

[6] Canadian Council of Academies (2014) *Science Culture: Where Canada Stands*. Expert Panel on the State of Canada's Science Culture (http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/science-culture/scienceculture_fullreporten.pdf

[7] *Ibid*, p. 55.

[8] *Ibid*, p. 76.

[9] Brochu, P., Deussing, M.-A., Houme, K., & Chuy, M. (2013). *Measuring Up: Canadian Results of the OECD PISA Study*. Ottawa, Ontario. Council of Ministers of Education, Canada.

[10] Canadian Council of Academies (2015) *Science Culture: Where Canada Stands*. Expert Panel on the State of Canada's Science Culture, *p*. 87.

[xi] Government of Canada (1985) *A National Science and Technology Policy Background Paper,* Ottawa, Ontario.

[xii] These six principles are to: improve industrial innovation and technology diffusion through public and private mechanisms; develop strategic technologies for manufacturing, service and resource-based sectors; assure the necessary pool of highly qualified people; support basic and applied research and development; control the impact of technological change on society; and promote a more science-oriented culture.

[xiii] Ministry of State for Science and Technology (1987) *Innovaction: the Canadian Strategy for Science and Technology*.

[xiv] National Advisory Board on Science and Technology (1995) *Healthy, Wealthy and Wise: A Framework for an Integrated Federal Science and Technology Strategy*;
see also http://www.parl.gc.ca/Content/LOP/researchpublications/bp414-e.htm#OVERVIEW

[xv] Government of Canada (2007) *Mobilizing Science and Technology to Canada's Advantage* (https://www.ic.gc.ca/eic/site/icgc.nsf/vwapj/SandTstrategy.pdf/$file/SandTstrategy.pdf)

[xvi] Government of Canada (2014) *Seizing Canada's Moment: Moving Forward in Science, Technology and Innovation* (https://www.ic.gc.ca/eic/site/icgc.nsf/vwapj/Seizing_Moment_ST_I-Report-2014-eng.pdf/$file/Seizing_Moment_ST_I-Report-2014-eng.pdf)

[xvii] See P. Dufour and Y. Gingras (1988) Development of Canadian Science and Technology Policy. *Science and Public Policy* 15(1): 13-18.

[xviii] See Expert Advisory Group on Government Science and Technology (2015) *ScienceCan: Enhancing the Value of Government Science, Engineering and Technology in Canada's Science and Innovation Ecosystem*, (2015). Vol. II Supporting Material, Appendix E, *p*. 40, Fig. 1.

[xix] Data are from CANSIM (Table 358-0142) (http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=3580142&&pattern=&stByVal=1&p1=1&p2=31&tabMode=dataTable&csid=) and the Parliamentary Budget Office.

[xx] *Ibid*. See also http://www.statcan.gc.ca/daily-quotidien/150528/cg-d001-eng.htm

[xxi] Data are from CANSIM Table 358-0144 , available at http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=3580144

[xxii] A chronology of program and facility closures under the current administration can be found at: http://scienceblogs.com/confessions/2013/05/20/the-canadian-war-on-science-a-long-unexaggerated-devastating-chronological-indictment/ . As several commentators have noted extensive cuts to federal S&T expenditures also occurred during the Paul Martin program review period during the early 1990s.

[xxiii] Professional Institute of the Public Service (2014) *Vanishing Science: the Disappearance of Canadian Public Interest Science*. Survey of federal government scientists by the Professional Institute for the Public Service of Canada. http://www.pipsc.ca/portal/page/portal/website/issues/science/vanishingscience

[xxiv] Science, Technology and Innovation Council (STIC) (2015), *Canada's Innovation Challenges and Opportunities, p*. 24, Fig 3.2. Available at *http://www.stic-csti.ca/eic/site/stic-csti.nsf/vwapj/STIC_1500_SON_Report_e_proof4.pdf/$FILE/STIC_1500_SON_Report_e_proof4.pdf*

[xxv] *Ibid*. *pp*. 24-25.

[xxvi] This set of core government S&T functions is adapted from: Expert Advisory Group on Government Science and Technology (2015) *ScienceCan: Enhancing the Value of Government Science, Engineering and Technology in Canada's Science and Innovation Ecosystem*, (2015). Vol. II Supporting Material, *p*. 40.

[xxvii] In this regard, a set of criteria by the Expert Advisory Group on Government Science and Technology is particularly informative. See endnote 27, Vol. I, *p*. 16.

[xxviii] See, for example, Science, Technology and Innovation Council (2015), *Canada's Innovation Challenges and Opportunities*, *p*. 3, available at: http://www.stic-csti.ca/eic/site/stic-csti.nsf/vwapj/STIC_1500_SON_Report_e_proof4.pdf/$FILE/STIC_1500_SON_Report_e_proof4.pdf

[xxix] The most recent data on Canadian BERD intensity performance are provided in the OECD *Science and Technology Indicators* database, available at http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB .

[xxx] The Conference Board of Canada report can be found at http://www.conferenceboard.ca/hcp/details/innovation/berd.aspx

[xxxi] See Science, Technology and Innovation Council (2015), *Canada's Innovation Challenges and Opportunities* (http://www.stic-csti.ca/eic/site/stic-csti.nsf/vwapj/STIC_1500_SON_Report_e_proof4.pdf/$FILE/STIC_1500_SON_Report_e_proof4.pdf). Canada's BERD performance is discussed in Chapter 2, see especially *pp*. 10-12.

[xxxii] *Ibid*. p. 12.

[xxxiii] A thorough examination of Canadian business investment in research and development is provided in the recent report by the Canadian Council of Academies, *Innovation and business strategy: why Canada falls short*, available at: http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/inno/(2009-06-11)%20innovation%20report.pdf According to the CCA, "both the weakness of business R&D and the disappointing level of university research commercialization appear to be two symptoms of the same underlying condition – a lack of orientation by Canadian business, on the whole, to the commercial exploitation of opportunities at the leading edge of science and technology." (*p*. 59).

[xxxiv] The reasons underlying Canada's poor business and industrial R&D performance have been explored in a number of recent reports: see, for example, Jenkins, T.; Dahlby, B.; Gupta, A.; Leroux, M.; Naylor, Robinson, D. and R. (2011) *Innovation Canada: a Call to Action*. Review of Federal Support to Research and Development. Report of Review Panel (http://rd-review.ca/eic/site/033.nsf/vwapj/R-D_InnovationCanada_Final-eng.pdf/$FILE/R-D_InnovationCanada_Final-eng.pdf); Canadian Council of Academies (2013a) *Paradox Lost: Explaining Canada's Research Strengths and Innovation Weaknesses* (http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/synthesis/paradoxlost_en.pdf); and Canadian Council of Academies (2013b) *The State of Industrial R&D in Canada* (http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/research%20and%20develop/ird_fullreporten.pdf)

[xxxv] This suggestion has been made by a number of institutions and stakeholders – see, for example, Science, Technology and Innovation Council of Canada (2015) *State of the Nation 2014: Canada's Science, Technology and Innovation System*, *p*. 3.

[xxxvi] Recently, the Australian government has released its national innovation science agenda (http://innovation.gov.au/page/national-innovation-and-science-agenda-report), which is moving ahead with a number of similar recommendations.

[xxxvii].See, for example, Jenkins, T.; Dahlby, B.; Gupta, A.; Leroux, M.; Naylor, Robinson, D. and R. (2011) *Innovation Canada: a Call to Action*. Review of Federal Support to Research and Development. Report of Review Panel, *p*. E-11 (http://rd-review.ca/eic/site/033.nsf/vwapj/R-D_InnovationCanada_Final-eng.pdf/$FILE/R-D_InnovationCanada_Final-eng.pdf .

[xxxviii] Jenkins, T.; Dahlby, B.; Gupta, A.; Leroux, M.; Naylor, Robinson, D. and R. (2011) *Innovation Canada: a Call to Action*. Review of Federal Support to Research and Development. Report of Review Panel (http://rd-review.ca/eic/site/033.nsf/vwapj/R-D_InnovationCanada_Final-eng.pdf/$FILE/R-D_InnovationCanada_Final-eng.pdf .

[xxxix] NRC *Strategy 2013-2018*; National Resource Council Canada: 2013**.**

[xl] Hoag, H. (2011). Canadian research shift makes waves. *Nature* 472: 269 doi:10.1038/472269a http://www.nature.com/news/2011/110419/full/472269a.html .

[xli] Canadian Association of University teachers (2013), Federal Funding of Basic Research *CAUT Education Review* 13: 1-6, available at http://www.caut.ca/docs/default-source/education-review/educationreview13-1-en.pdf?sfvrsn=2 .

[xlii] See, for example, K. Birchard and J. Lewington (2014) Dispute over the future of Basic Research in Canada. *New York Times*, Feb. 17 (http://www.nytimes.com/2014/02/17/world/americas/dispute-over-the-future-of-basic-research-in-canada.html); J. D. Neufield (2013), The plight of basic research in Canada. *iPolitics,* Oct 21, available at http://ipolitics.ca/2013/10/21/blinded-to-science-the-plight-of-basic-research-in-canada/

[xliii] In February 2013, the University Of Victoria's Environmental Law Clinic and the NGO *Democracy Watch* petitioned Information Commissioner Suzanne Legault alleging that the government's policy restrictions on science communication represented a breach of the Access to Information Act (http://democracywatch.ca/wp-content/uploads/OpenGovReportJan2113.pdf). In her 2014-2015 annual report (p. 49), the Commissioner indicated that this allegation is still being investigated, with resolution expected in 2016 (http://www.oic-ci.gc.ca/telechargements-downloads/userfiles/files/eng/reports-publications/annual-reports/2014-2015/OIC_15-351_AR2015_updates_E_WEB2%20-%20Updated.pdf)

[xliv] The *Values and Ethics Code for the Public Sector* holds that "Federal public servants have a fundamental role to play in serving Canadians, their communities and the public interest under the direction of the elected government and in accordance with the law." It further specifies (s. 1.2) that public servants should uphold Canadian parliamentary democracy and its institutions by
"Loyally carrying out the lawful decisions of their leaders and supporting ministers in their accountability to Parliament and Canadians."

[xlv] An annotated listing of a number of such events can be found in the Federal Information Commissioner's 2014-2015 report – see endnote 44.

[xlvi] Professional Institute of the Public Service (2013) *The Big Chill: Silencing Public Interest Science, A Surve**y,*** available at http://www.pipsc.ca/portal/page/portal/website/issues/science/bigchill

[xlvii] K. Magnuson-Ford and K. Gibbs (2014) *Can Scientists Speak?* Evidence for Democracy, Ottawa (https://evidencefordemocracy.ca/sites/default/files/reports/Can%20Scientists%20Speak_.pdf)

[xlviii] See, for example, A. Leach (2014) Unmuzzle the scientists? Not so fast. *MacLeans*, Aug. 24 (http://www.macleans.ca/economy/economicanalysis/un-muzzle-the-scientists-not-so-fast/); P. Cross (2013) What war on science? *Financial Post*, Oct 21 (http://business.financialpost.com/fp-comment/what-war-on-science); see also *p.* 50 of Expert Advisory Group on Government Science and Technology (2015) *ScienceCan: Enhancing the Value of Government Science, Engineering and Technology in Canada's Science and Innovation Ecosystem*, (2015). Vol. II (Supporting Material)

[xlix] See, for example, C.S. Findlay (2013) Junk science and muzzling scientists redux. *Financial Post*, June 19 (http://business.financialpost.com/uncategorized/fp-letters-junk-science-and-muzzling-scientists-redux); T. Hsu, M. Rennie and C.S. Findlay (2015) Unmuzzle the scientists? Critics say: "Yes please". *MacLeans*, Aug. 26 (http://www.macleans.ca/society/science/un-muzzle-the-scientists-mp-ted-hsu-responds/); C.S. Findlay (2014) Government scientists should be allowed to speak for themselves. *Toronto Star*, Aug. 25

(http://www.thestar.com/opinion/commentary/2014/08/25/government_scientists_should_be_allowed_to_speak_for_themselves.html)

[l] See, for example, M. Hume (2015) Federal scientists eager to share their research now that muzzles are off. *Globe and Mail*, Nov. 8, 2015 (http://www.theglobeandmail.com/news/british-columbia/federal-scientists-eager-to-share-their-research-now-that-muzzles-are-off/article27171269/)

[li] As part of their election platform, the Liberal Party of Canada proposed the creation of Chief Science Officer whose role would be to "ensure that government science is fully available to the public, that scientists are able to speak freely about their work, and that scientific analyses are considered when the government makes decisions." (https://www.liberal.ca/realchange/science-and-scientists/)

[lii] See, for example, Green Party Leader Elizabeth May's remarks on introducing her Open Science bill during the last sitting of Parliament: http://www.greenparty.ca/en/media-release/2015-06-18/elizabeth-may-introduces-open-science-bill . See also: http://www.theguardian.com/world/2015/oct/16/elizabeth-may-canada-green-party-leader-election-profile

[liii] Examples include the minimum mandatory sentencing provisions of Bill S-10 for drug-related crimes (http://www.theglobeandmail.com/news/politics/ottawa-notebook/health-researchers-slam-tory-mandatory-minimum-sentence-proposal/article611514/) and recent amendments of the habitat protection provisions of the Fisheries Act – see J. A. Hutchings and J.R. Post (2013) Gutting Canada's Fisheries Act: No Fishery, No Fish Habitat Protection. *Fisheries* 38:497-501, available at http://fisheries.org/docs/fisheries_magazine_archive/fisheries_current.pdf .

[liv] See, for example, the case of Dr. Munir Sheikh's resignation over then Industry Ministry Tony Clement's public statement that Statistics Canada had assured him that the proposed (voluntary) National Household Survey would be an adequate substitute for the mandatory long-form census (http://www.theglobeandmail.com/globe-debate/the-munir-sheikh-matter-was-no-technicality/article1389761/); Minister of Health Rona Ambrose's public assertion that there was no evidence of the efficacy of medical-grade opiates in the treatment of drug addiction, despite overwhelming evidence to the contrary (http://ipolitics.ca/2014/08/22/the-harper-governments-lonely-struggle-against-reality/); and the representation of voter fraud by then Minister of Democratic Reform Pierre Poilievre (http://www.huffingtonpost.ca/2014/03/07/pierre-poilievre-voter-fraud-fair-elections-act_n_4917506.html)

[lv] Particularly noteworthy examples include the Australian Productivity Commission's 2009 report *Strengthening Evidence-based Policy in the Australian Federation* (http://www.pc.gov.au/research/supporting/strengthening-evidence); the UK House of Commons Science and Technology's 2007 report *Scientific Advice, Risk and Evidence Based Policy Making* (http://www.publications.parliament.uk/pa/cm200506/cmselect/cmsctech/900/900-i.pdf) and the New Zealand Chief Science Advisor's report on strengthening evidence-informed decision-making http://www.pmcsa.org.nz/wp-content/uploads/The-role-of-evidence-in-policy-formation-and-implementation-report.pdf .

[lvi] The issue of what constitutes "best practices" for science advice has been widely examined. In brief, those who would provide science advice should act as a "honest brokers" (Pielke, R. A. Jr *The Honest Broker: Making Sense of Science in Policy and Politics*(Cambridge Univ. Press, 2007).). Several summaries of the principles that should guide science advice have been produced- see for example, Gluckman, P. Nature 507, 163–165 (13 March 2014) doi:10.1038/507163a available at http://www.nature.com/news/policy-the-art-of-science-advice-to-government-1.14838

[lvii] The SAGE report is available at http://artsites.uottawa.ca/sca/doc/SAGE_e.pdf . A companion document that provides a set of principles and guidelines for the effective use of science and technology advice in government decision-making can be found at: http://publications.gc.ca/collections/Collection/C2-500-2000E.pdf .

[lviii] These principles are available at http://www.zoology.ubc.ca/~otto/SIP2015/documents/SIP_Statement_of_PrinciplesGraphic.pdf . For a historical perspective on science integrity in government, see P. Dufour and M. Ryan (2015) The evolving context of science integrity in Canada. *The Science Integrity Project*. Available at: http://www.zoology.ubc.ca/~otto/SIP2015/documents/SIP_background.pdf

[lix] Royal Society of Canada (2015) *Strengthening government by strengthening scientific advice: fully realizing the value of science to Canadian society*. RSC Position Paper, May 2015, available at https://rsc-src.ca/sites/default/files/pdf/PP_SA_EN_0.pdf .

[lx] Minster of Science Mandate Letter, available at http://pm.gc.ca/eng/minister-science-mandate-letter

[lxi] This set of recommendations draws heavily on Bill C-558 (The Parliamentary Science Officer Act), introduced by NDP Science and Technology critic Dr. Kennedy Stewart (http://kennedystewart.ndp.ca/sites/default/files/multisite/132220/IMCE/bill_c-558.pdf), as well as recommendations from the Royal Society of Canada available at https://rsc-src.ca/sites/default/files/pdf/PP_SA_EN_0.pdf .