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Reflections on science advisory systems in Canada

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ABSTRACT As the evolution of our world has triggered complexity and technological sophistication, it is now essential to consider sound scientific evidence as an integral element of decision-making. Science advisers or chief scientists have to take into account many factors in giving advice. Depending on the nature and level of advice, factors such as the ideology of the governing body, the state of the social, economic and scientific development in the country or region, potential impacts on the health, environment and security of the community, the balance of risk and reward in various options, must all be considered. Canada has lived through a few of these issues in its recent experience with science advice and advisory systems. This article will elaborate on the impact and influence of changes in science advisory bodies at the federal and Quebec government levels and will provide a perspective on their impact. It examines the historical evolution of the advisory apparatus for science throughout Canada's history and underscores some of their successes and failures under different regimes. The conclusion drawn in this article is that science and science advisory systems in Canada have lacked continuity and a solid foundation thus weakening efforts to enable sound science-based policy into decision-making. The article argues for a more institutionalized and pluralistic approach to ensuring that evidence and science advice can endure—both at the federal and provincial levels. In many ways, the experience with these advisory mechanisms suggests a growing need to ensure sound advice within increasingly complex decision-making as well as a demand by citizens to have scientific evidence considered more carefully in public policy and for the public interest. This article is published as part of a collection on scientific advice to governments.

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Introduction

Over the past few years there has been a global renaissance of interest and debate on the issues of science advice to government, science advisory structures and the role of chief science advisors within these advisory systems. For the purpose of this article, we define science advice as the process, structures and institutions through which governments and decision makers receive and consider science and technology inputs to public policy development. We take the inclusive view of science as the natural, social, engineering and applied sciences and technologies.

Several new initiatives have been launched, including the establishment of a UN Scientific Advisory Board to advise the Secretary General and the appointment of a seven-person scientific advisory mechanism to the President of the European Commission. A revised Inter-academy Partnership is bringing together established global networks of academies of science, medicine, engineering and social sciences into a new collaboration, with academies working together across disciplines to support the special role of the sciences in an effort to seek solutions to the world's most challenging problems. Parallel with these new initiatives, there have been conferences or summits to discuss good practices in this area, including 2014 events in Auckland hosted by ICSU and the New Zealand Chief Science Advisor, Sir Peter Gluckman, as well as a preceding meeting of Chief Scientists and Opinion Leaders in Montreal convened by Quebec's Chief Science Officer, Dr Rémi Quirion. A new International Network for Government Science Advice (INGSA) has also been established (http://www.ingsa.org).

INGSA provides a forum for policymakers, practitioners, academies and academics to share experience, build capacity and develop theoretical and practical approaches to the use of scientific evidence in informing policy at all levels of government. A book of collected essays regarding future directions for scientific advice by Doubleday and Wilsdon adds to the wealth of published work on the topic and the OECD has published a set of common principles for scientific advice (Arimoto and Sato, 2012; OECD, 2015).

Various national academies of science are offering advisory statements to the G20 and other political players to coincide with special themes having a knowledge component, in the hopes that someone will listen. Countless national advisory committees are providing input into the decision-making processes of their respective economies. The next generation of younger scientists is also engaged in the establishment of the Global Young Academy and there is now a growing movement mobilizing greater citizen engagement in science advice (http://www.globalyoungacademy.net).

In the United Kingdom and the United States, considerable effort and policy focus has centred on providing access for chief scientists or science advisors to the highest levels of government, as well as within ministries or departments that must address science-based public policy issues. Guidelines and codes of practice for the most effective use of scientific advice in government advisory bodies have been drawn up in the United Kingdom, Japan, New Zealand and in other countries. The emergence of sets of principles guiding the provision of science advice to governments led by the Office of the Chief Science Advisor in the United Kingdom and Sir Peter Gluckman in New Zealand has stimulated a broader dialogue on the practice of science advice (Gluckman, 2014). A systems approach based on a three-pillar structure of advice from: formal channels (for example, Chief Science Advisors, national academies); informal channels (for example, advisory panels) and advisory systems for crisis situations (for example, a specific trusted individual with access to an information gathering infrastructure) has been widely discussed at conferences and in the European Union where a new Science Advice Mechanism is evolving.

In contrast to the progress made globally over the last decade on the development of principles, frameworks and systems for providing science advice to government, the overall situation in Canada has deteriorated significantly since the early 2000s. In 2000, the Federal Cabinet approved a report of the Council of Science and Technology Advisors (CSTA), a government advisory body, entitled SAGE (Science Advice for Government Effectiveness), which essentially provided a set of six key science advice principles to improve science-based decision-making and also a set of guidelines on the adoption of these principles. These principles have much in common with those adopted in the United Kingdom and more precisely defined by Gluckman (2014). Unfortunately for Canada, the CSTA was abandoned by the Federal Government in 2007 and the SAGE report shelved. This and the closing of the Office of the National Science Advisor (NSA) in 2008 were body blows to the science advisory system in Canada. Over 10 years of the Harper Conservative government, managers, communications strategists and advisors perfected the art of controlling and blocking access to federal scientists, essentially "muzzling" researchers and preventing them from communicating their science to the public and their counterparts in other countries (O'Hara and Dufour, 2014).

With the election of the Liberal Government in 2015, Prime Minister Trudeau has vowed to reopen the lines of science communication and "unmuzzle" federal scientists. Further, the newly appointed Minister for Science has been mandated by the Prime Minister (PM) to create a Chief Science Officer position whose task is 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. A consultation, led by the Minister, is underway to receive views on the nature and role of this new position.

How do we account for this revival of interest? Is it simply that the establishment of these new advisory positions and councils has drawn greatly increased attention? Could it be an upsurge of interest because public authorities are seeking greater guidance on complex policy matters where science is an important element? (Achenbach, 2015). Is scepticism about science causing reasonable people to doubt?

With the increasing complexity and technological sophistication of our world, it is clear that sound scientific advice is now considered a *sine qua non* for understanding the evidence base upon which decisions are made.

Science advisors or chief scientists must face all sorts of challenges: some dare to challenge the conventional or ideological position of the ruling government—often at some cost. Some are brought in to deal with crises that affect the very heart of economic survival and social development for a country or region. Many are ambassadors for branding their respective economies through international dialogue and trade missions.

This article explores more deeply the impact and influence of the science advisory experiments at the federal and Quebec government levels. In many ways, the experience with these advisory mechanisms suggests a growing need to ensure sound advice within increasingly complex decision-making systems as well as a demand by citizens to have scientific evidence considered more carefully in public policy and for the public interest.

Certainly, these and other aspects of assisting policy-making through science have many dimensions—but ultimately, the issue revolves around the nature of democracy with the requisite freedom of thought and the responsibility of scientists in such societies to contribute to a more informed and activist citizenry.

The question then becomes, how should the institutions of science advice be structured to ensure the functions of science in democratic states can be performed? To situate this analysis in the global context, Table 1 summarizes the science advisory models in place in 15 different countries or regions. In the following section, we will describe Canada's experiments and experience with science advisory systems.

Canada and Quebec: a brief history of science advisory systems and science advisers

In this section, we will briefly describe the history and current extent of science advisory systems in Canada, first at the federal level and then at the provincial level in Quebec. It is important to mention here that education and higher education are under provincial jurisdiction in Canada, including the funding of universities (all public) and colleges. Moreover, the majority of the higher education system in Quebec functions in French. It is two of the reasons explaining why the Quebec government decided to create its own research councils (the first one in the health sector more than 50 years ago) at least 20 years before any other provinces. And in 2011, the Quebec government created the position of Chief Science Officer opting for a hybrid model distinct from either the British (mostly advisory) or Israel (head of funding councils) model. The Quebec Chief Science Officer combines an advisory role to government on matters of science and innovation in addition to acting as executive officer of its three main research funding councils. Quebec is still the only province having created a Chief Science Officer position, while others are now exploring this possibility.

Canada. In the first half of the twentieth century, a period that included two world wars, the principal sources of scientific advice to Canadian Governments were the National Research Council (NRC) of Canada, through its President and Committees, and (to a lesser extent) the Royal Society of Canada (RSC) (discussed further below). It was not until 1964 that a Science Secretariat, based in the Privy Council Office, was set up to provide information on scientific matters on request from the PM and Cabinet. The creation of the Science Council of Canada (SCC) followed in 1966. This body was a Crown corporation, at arm's length from Government, charged with advising on the country's scientific and technological resources and on the effective deployment and utilization of scientific and technical personnel in Canada. It conducted its work in public and provided recommendations on various issues through reports and other publications. The SCC had a relatively long life for a science advisory body, but was eliminated by the Conservative Government in 1992 (Dufour and de la Mothe, 1993). We will return to the SCC and its function later in this article.

In 1969, a Chief Scientific Advisor (CSA) to Cabinet was appointed. The CSA also served as Director of the Science Secretariat (Uffen, 1972). With the subsequent creation of a Ministry of State for Science and Technology, a position of CSA to that Ministry was named in 1983. This was effectively a Deputy Minister position. The office was to advise the government on: (1) the integration of a long-range scientific perspective into the policy development process and into specific proposals before the Cabinet; (2) the identification of areas that are science and technology intensive and that would have a significant impact on Canada; (3) the quality and effectiveness of science and technology policies. Importantly, the CSA had no responsibilities for coordinating the federal government's S&T budget allocations.

The Royal Society of Canada (RSC). Both the NRC and the RSC have been engaged in science advice at various times in their

Table 1 | Science advice by country-region: selected cases

Country-region	*National academy*	*Main responsibility for advice to government*	*Chief advisor*
Australia	Australian Academy of Science	Chief Science Adviser and Commonwealth S&T Advisory Council to the PM	Prof. Alan Finkel
Austria	Die Österreichische Akademie der Wissenschaften	President of the Austrian Academy of Sciences	Prof. Dr Anton Zeilinger
Canada	Royal Society of Canada; Council of Canadian Academies	Advisory Committee—STIC	—
Quebec	—	Chief Science Officer	Dr Rémi Quirion
Cuba	Academia de Ciencias de Cuba	Chief Science Adviser	Prof. Castro Díaz-Balart
Denmark	Royal Danish Academy of Sciences and Letters	President, Advisory Committee	Prof. Kirsten Hastrup
France	Académie des Sciences	Hybrid model	—
Germany	Deutsche Forschungsgemeinschaft (DFG) and German Academy of Sciences Leopoldina	Hybrid model	—
Greece	Academy of Athens	Advisory Committee	—
India	—	Principal Scientific Adviser to the Government of India & Chairman Scientific Advisory Committee to Cabinet	Dr R Chidambaram
	—	Chairman, Scientific Advisory Council to the Prime Minister	Prof. CNR Rao
Ireland	Royal Irish Academy	Chief Science Adviser	Sir Mark Ferguson
Kenya	Kenya National Academy of Sciences	—	Prof. Shaukat A Abdulrazak
Malaysia	Academy of Sciences Malaysia	—	Prof. Zakri Abdul Hamid
New Zealand	Royal Society of New Zealand	Chief Science Adviser	Sir Peter Gluckman
Portugal	Academia das Ciencias de Lisboa	Advisory Committee	—
United Kingdom	Royal Society	Chief Science Advisers in all departments	Sir Mark Walport
United States of America	National Academy of Sciences	Science Adviser to the President and Director OSTP	Dr John Holdren

respective histories. Established in 1882 as Canada's National Academy, the RSC's main objective is to promote learning and research in the arts, the humanities and the natural and social sciences. From time to time, the RSC has engaged in science advice, particularly during the late 60s and 70s when the science advisory machinery was being put into place. Early reports on science communication (1978) and the future of molecular biology (1983) were examples of its work. It has also played a role in alerting the government to upcoming issues, including the need for a Canadian AIDS strategy and policy gaps in critical health issues such as early childhood education, asbestos, acid rain and lead in gasoline. More recently, the RSC has also weighed in with a position paper on strengthening science advice to government as well as offering advice to the Science Minister on the role of a proposed Chief Science Officer (Royal Society of Canada, 2015).

The RSC, a founding member of the Council of Canadian Academies (CCA) (discussed below), launched an expert panel initiative in the early 2000s, with a mandate to carry out independent, authoritative, evidence-based expert panel assessments to inform public policy development. The reports are independent in nature and have tackled such broad issues as euthanasia, exposure from radiofrequency fields and the future of libraries. A Statement of Common Understanding was initiated in 2011 among the founding member organizations of the CCA established in 2005 (which also includes the Canadian Academy of Engineering and the Canadian Academy of Health Sciences (CAHS)) to guide more effective collaboration. As one example, in 2010, the CAHS asked the Council to manage the process for an evidence-based assessment on Canada's current role in global health, to assess its comparative advantage in the context of global health needs and to articulate a rationale for Canada to play a more significant role in global health leadership (*Canadian Academy of Health Sciences, Canadians Making a Difference: The Expert Panel on Canada's Strategic Role in Global Health, 2010*). In 2013, another joint effort led to a report on so-called conducted energy weapons and their health effects (*CCA, the Health Effects of Energy-Conducted Weapons, 2013*).

Quebec. When Quebec was establishing its first science policy in the early 70s, it also examined the potential for a science advisory policy structure and established the *Conseil de la politique scientifique* (CPS). In its science and research policy report of 1980, *Un Projet Collectif*, the Quebec government argued for a transparent and open advisory system. As the White Paper underscored, the government wanted to do away with the secrecy with which the work of various advisory bodies on scientific research policy was carried out. A re-examination of the membership of the advisory bodies was recommended to ensure that representatives on these bodies favoured a real exchange between the scientific community, scientific and political decision makers, social groups and the general public.

The White Paper also made the case for encouraging various forms of consultation to ensure a true civic engagement such as promoting the development of the scientific press and media and inviting scientists to participate in various public debates.

In 1983, Quebec restructured its advisory process and established a *Conseil de la science et de la technologie* (CST) (Table 2). For over three decades, the Conseil was a major force enlivening and informing the dialogue for science and technology in society. It produced a wide array of thoughtful and practical reports for numerous Quebec administrations over its life span. Many of its recommendations had an impact on policy-making and on science culture. The Conseil's reports are now archived and can be accessed by historians and others to remind us of debates past, policy portends of the future, and, opportunities lost

Table 2 | A chronology of Quebec advisory bodies

1971	Ministerial Committee of Science Policy
1972	Conseil de la politique scientifique
1980	Minister of State for Scientific Development
1982	Delegated Minister for Science and Technology
1983	Creation of Ministry for Science and Technology
1983	CPS becomes a new Conseil de la science et de la technologie
1984	Ministry of Higher Education, Science and Technology
2011	Abolition of CST—creation of a Chief Scientist position for Quebec*
2015	Ministry of Education, Higher Education and Research

*Québec, *Le Développement scientifique au Québec*, Ministère de l'Enseignement Supérieur et de la Science, 1992

(the Conseil also produced a useful 30-year history in 2002 that provides an excellent perspective of its scope).

The Conseil was also requested to produce a regular *rapport de conjuncture* (State of the S&T Report). Its last was on the emerging trends in open innovation, something both the federal Science, Technology and Innovation Council (STIC) and the CCA have tried to emulate. The Quebec Conseil provided all of its advice in an open environment allowing for strong debate around central questions of how and, with what implications, do knowledge and society intersect.

The CST had other notable features, several of which were analogous to its former sister organization—the SCC.

The CST could:

- Concentrate on long-range, often intractable problems, and conduct in-depth studies (improving science culture and education in schools)
- Work on detection of future problems, providing an early warning function to help influence government policies and priorities (emerging technologies, neurosciences, nanotechnology and biotech)
- Take expert positions without necessarily implicating the government directly; hence because of its credibility it could stimulate and actively participate in parliamentary and other societal discussions (future of the social sciences, foresight for technology)
- Undertake studies at the request of government and engage in international assessments ("state of science" report on globalization)
- Bring to bear public input and expertise of a wide cross section of eminent people through an institutional structure designed to express their objectivity and autonomy (long-term perspectives or grand challenges affecting Quebec society)
- The CST had a strong institutional memory that provided important checks and balances in policy-making and it was not limited by politically sensitive considerations (for example, the impact of federal R&D programs and investments in Quebec)

Above all, the CST was a reflection of how Quebec viewed the importance of the growing interface of science, culture and innovation in society; it also served as an important training ground for future decision makers and scholars. In 1986, the Conseil, at the request of the then Minister of Higher Education and Science, produced an interesting background document to examine the organization of S&T policy in Quebec (Conseil de la science et de la technologie, 1986). In part, this had been triggered by a need to have a stronger and more efficient capacity to address the province's ability to interface with the federal government and its analogous S&T governance structures. Quebec had also been experimenting with various governance

models for science and technology and the various forms of Ministries for higher education, science and technology had been tried from time to time.

The report examined six different models for informed science advice at the Cabinet decision-making level. It explored the pros and cons of each of the following models:

- A science adviser to the Premier
- A sector specific Minister responsible for S&T
- A delegated Minister to the Premier
- A horizontal Minister of State (across government)
- An Advisory Council to the Minister
- An Advisory Council for coordination

The Canadian experience

Table 3 outlines some of the key Canadian science advisory instruments in play from 1882 to 2015. With the SCC eliminated in 1992 and national elections changing the government from conservative to liberal in 1993, major revisions in the science advisory system in Canada were imminent. The National Advisory Board on Science and Technology (NABST) was abolished and a new Federal S&T Strategy was announced in 1996. The Liberal government then introduced a new science governance advisory structure. The CSTA was to provide Cabinet with external expert advice on internal federal government science and technology issues. It was chaired by the Secretary of State for Science, Research and Development and its 22 members were nominated from their Advisory Boards/Councils by Ministers of science-based departments and agencies. The CSTA was initially asked to develop a set of principles for the effective use of science advice in government decision-making as well as an examination of the role of the federal government in performing S&T and its ability to fulfil this function. Over its 10-year life span, it produced and published several key reports on how to address these critical issues.

Table 3 | Canadian institutional and policy instruments for science advice

1882–	Royal Society of Canada
1916–	National Research Council (Honorary Advisory Council on Scientific and Industrial Research)
1964–1971	Science Secretariat (PCO)
1964–1992	Science Council of Canada
1972–1983	Conseil de la politique scientifique—Québec
1983–2011	Conseil de la science et de la technologie-Québec
1987–1996	National Advisory Board on Science and Technology (originally called the National Board on Industrial Technology)
1988–1993	National Forum of Science and Technology Councils
1996–2008	Advisory Council on Science and Technology
1998–2008	Council of Science and Technology Advisors
2003–2008	National Science Advisor to the Prime Minister
2007–	Science, Technology and Innovation Council
2005–	Council of Canadian Academies (formerly Canadian Academies of Science)
2011–	Chief Scientist of Quebec
Other	—
Various reports	House of Commons Committee on Industry, Science and Technology Auditor General of Canada assessments of Canada's science policies
1969–1977 (four volumes)	Lamontagne Special Senate Committee on Science Policy in Canada

The list is given below (these reports are all available at http://artsites.uottawa.ca/sca/en/council-of-science-and-technology-advisors/):

- Science advice for government effectiveness (SAGE-1999)
- Building excellence in science and technology (BEST-1999): The federal roles in performing science and technology
- Science and technology excellence in the Public Service (STEPS-2001): a framework for excellence in federally performed science and technology
- Reinforcing external advice to departments (READ-2001)
- Employees driving government excellence (EDGE-2002)
- Science communications and opportunities for public engagement (SCOPE-2003)
- Linkages in the national knowledge system: Fostering a linked Federal S&T enterprise (LINKS-2005)
- Facing opportunities and challenges underlying society: Federal S&T Management in the twenty-first century

The most influential of the reports was its first (CSTA, 1999). Following the public controversies surrounding such issues as dwindling fish stocks, the contamination of Canada's blood supply, GMOs and growth hormone use in dairy cows, the SAGE report of 1999 was adopted by the federal Cabinet in 2000 as a series of principles and guidelines for the effective use of S&T advice in government decision-making. The framework borrowed from a similar set of principles developed earlier in the United Kingdom (UK, DTI, 1997)

The SAGE report advised:

- Government needs to anticipate, as early as possible, those issues for which science advice will be required
- Advice should be drawn from a variety of scientific sources and from experts in relevant disciplines
- Government should employ measures to ensure the quality, integrity and objectivity of the science and science advice it uses, and ensure that science advice is considered in decision-making
- Government should develop a risk management framework that includes guidance on how and when precautionary approaches should be applied
- Government is expected to employ decision-making processes that are open, as well as transparent, to stakeholders and the public
- Subsequent review of science-based decisions is required to determine whether recent advances in scientific knowledge have an impact on the science advice used to reach the decision

While the mandate of CSTA was focused on the provision of external advice to inform internal government S&T issues, the Advisory Council on Science and Technology (ACST) (Table 4), created in 1996, was an external body designed to advise the Minister responsible on the country's performance in S&T; to identify emerging issues and advise on a forward-looking agenda. That body, consisting of 12 members appointed by the PM, produced four reports before it was eliminated—along with the CSTA in 2007.

Appointment of a National Science Adviser

When the new Liberal PM Paul Martin came into power in 2003, he appointed his own National Science Adviser. Dr Arthur Carty, former President of the NRC, took up these functions in April 2004 in the Privy Council Office. The core mandate of the National Science Adviser was to provide advice to the PM. To develop a stronger base of information, the NSA quickly

Table 4 | A comparison of the structure, membership and output of NABST and ACST

The National Advisory Board on Science and Technology (NABST)	*The Advisory Council on Science and Technology (ACST)*
• Chaired by PM • 41 members initially then 24 (with government ministers ex-officio) • Four to six meetings per year • 24 reports • Reports on gender in science, public awareness, government science, national priorities	• Chaired by PM once, then Secretary of State for Science, R&D • 11 members including ex-officio ministers • Six meetings per year • Four reports published on commercialization of university research, international, skills and indirect costs

Table 5 | A comparison of the structure, membership and reports of SCC and STIC

Science Council of Canada (SCC)	*Science & Technology Innovation Council (STIC)*
• Chaired by a prominent Canadian; supported by Secretariat • Reported to Parliament • 22 members • Over 400 reports in lifetime —all public • 29 staff at dissolution	• Chaired by a former Deputy Minister of Ontario Government • Reports to Minister of Science with Secretariat • 19 members • Four public reports (state of science and technology in Canada) and one public advice (S&T sub-priorities)

commissioned a study of science advisory structures in various countries. However, with a change of government in 2006, the NSA's office was transferred in May from the Privy Council Office to the Minister of Industry and asked to give advice on matters of strategic importance to Canada in science, technology and innovation (STI) policy. The transfer did not sit well with the bureaucrats in the Department of Industry who felt that they did not need such an office, nor any advice.

With the new Harper Government then in place, the Deputy Minister of Industry Canada commissioned Dr Howard Alper of the University of Ottawa to produce a background paper and to provide a report on science advice and science advisory bodies to the highest levels of government. In this report, Alper recommended that the government replace the ACST, the CSTA and the NSA by a Canadian S&T Council chaired by then Prime Minister Harper. This recommendation was partially followed. However, Alper became the first Chair of the newly established STIC in 2007 to provide confidential advice—but to the Minister of Industry, not the PM (Table 5). Nor would the PM chair the new body. Another consequence of these changes was that the Canadian Biotechnology Advisory Committee (CBAC) was also eliminated.

Seen in retrospect the abandonment of the CSTA, ACST, CBAC and the Office of the National Science Advisory by the Harper Government was a body blow to the science advisory system in Canada and a setback which endured for a decade. Meanwhile, the NSA continued with his mandate. Between April 2004 and May 2008, key issues on which the NSA was principally engaged included the following initiatives, several of which continued after the Office of the NSA was dissolved.

The Council of Canadian Academies (CCA). The NSA was actively engaged in advocating the establishment and funding of the Canadian Academies of Science—now known as the CCA—as an independent, arms-length body to provide expert panel assessments on the science underpinning issues of importance to government.

The CCA is a federally incorporated, not-for-profit organization that joins together Canada's three internationally recognized national academies and is modelled in part after the US National Academies of Science.

Announced in the October 2004 Speech from the Throne, and funded in the federal budget of 2005 with US$30 million over 10 years, the mandate of the CCA is to:

- Carry out government requests of independent expert assessments on the state of scientific knowledge underpinning policy issues facing Canadians
- Ensure that Canada is represented effectively in international fora where important questions of scientific methods and findings are being discussed

The CCA has produced more than 34 Expert Panel Reports since it became functional in 2005. There is some concern over the fact that: the CCA is dependent on renewal of its funding from the federal government (in 2015, it received a 5-year allocation of $15 million); that ministers can request narrow remits for the advice given; and that the CCA is not supposed to make any recommendations in its reports. Yet it still serves as a useful vehicle for creating publicly available advice drawing from expertise across disciplines and industry sectors (for more on the CCA, see http://www.scienceadvice.ca).

A framework for major science investments (MSIs). In collaboration with the heads of Research Councils and Agencies, the NSA led the development of a "Framework for the Evaluation, Funding and Oversight of Canadian MSIs" and convened a national consultation process to finalize a transparent process for the consideration of Canada's "big science" investments. In 2015, the Canada Foundation for Innovation President resurrected this suggestion and argued that the new Liberal government would need to mandate a national body to undertake a full-scale review. It could determine the areas in which Canada should invest in large-scale infrastructure and research, particularly with respect to such highly expensive disciplines as particle physics, astronomy and Arctic research, but also in areas of major international collaborative research in biomedicine (for example, dementia or antimicrobial resistance). Investment in cyber-infrastructure and high-speed computing might also be priorities (Kondro, 2015).

Assessment of nanotechnology in Canada. Nanotechnology is a rapidly evolving disruptive and enabling technology with broad potential applications across virtually all sectors of the Canadian economy. In close collaboration with the PM's ACST, the NSA chaired an international panel of experts for an assessment of Canadian research strengths in nanotechnology. This report formed the basis of a recommendation to government to implement a national strategy for nanotechnology. This was never adopted.

Positioning Canada in international research and development. While the NSA had a broad national remit for the federal government, the position also required a strong ambassadorial and marketing function abroad. The perception of Canada's strengths and its responsibilities as a global knowledge player was heavily influenced by the messages conveyed through the NSA function. Further, the impact of international events and

initiatives on Canada's innovation agenda was viewed as an important dimension of any science advisory capacity.

Several key initiatives that were enabled through the engagement of the NSA were:

- The mobilization of the Canadian federal research community around the International Polar Year and the agreed 5-year funding of $150 million in 2005
- The development of an action plan to bring the benefits of Canadian research and development to bear on the challenges faced by the developing world
- The mobilization of S&T efforts in Canada to collaborate with emerging markets, including China, India and Brazil through the International S&T Partnerships Program adopted in Budget 2005 and resulting in the first bilateral S&T agreements with Brazil, India and China
- The representation of Canada on the Carnegie Group of Science Advisors and Science Ministers that meets yearly. This group worked to strengthen Canadian S&T efforts around key G8 commitments such as capacity building in S&T for Africa and emerging infectious diseases (Carty and Dufour, 2010)

Integration and coordination of science policy in Canada. In the October 2004 Speech from the Throne, the NSA was tasked to assist the Government to "ensure that Canada's investments in Science and Technology are strategic, focused and delivering results, and to bring about a fuller integration of the government's substantial in-house science and technology activity". In an effort to achieve this goal, the NSA undertook several initiatives to improve the coordination and linkages between government agencies and departments and other elements of the research ecosystem, including an examination of science culture in Canada based on one of the recommendations issuing from the Federal S&T strategy in 2007. This last task was ignored by the host department Industry Canada, but appropriately, Dr Carty was subsequently asked in 2013 to chair an expert panel of the CCA on the very same question (CCA, 2014).

Commercialization of research. In the March 2004 federal budget, the NSA was asked to work with the Minister of Industry to study how the commercialization environment in Canada could be improved and how in the longer term Canada could be at the leading edge of commercializing its intellectual property assets.

The key findings of the NSA's consultations with a broad range of industry stakeholders were shared with the Rotman Expert Panel on Commercialization in June 2005 and reflected in the final report of the Panel, "People and Excellence: The Heart of Successful Commercialisation", as well as in the 2006 Conference Board of Canada's Leaders Roundtable on Commercialization, "Picking a Path to Prosperity, A Strategy for Global Best Commerce". Both reports came to similar conclusions and formed the basis of a response from the Government of Canada to address the commercialization challenges facing the country in the coming decade:

- Talent, skills and people
- Investment and risk capital
- Research and linkages

In 2007 with the release of the May federal strategy for science and technology, and picking up on some of the recommendations from the Alper report to the Industry Canada Deputy Minister, the ACST, CSTA and NSA were terminated and replaced with a new confidential advisory council to the Minister of Industry—STIC. STIC is an advisory body mandated by the Government of Canada to provide confidential advice on STI policy issues. This advice helps inform government policy development and decision-making. STIC is also mandated to produce biennial, public State of the Nation reports that benchmark Canada's STI performance against international standards of excellence. These reports provide a common evidence base for understanding Canada's STI system.

In March 2008, the House of Commons Committee on Industry, Science and Technology convened a special hearing on the reasons for the closure of the Office of the National Science Advisor (ONSA) and asked Dr Carty to testify. The meeting was essentially divided along partisan lines with the Conservative members driving to discredit the work of the NSA, and the opposition parties demonstrating the need for such a position.

As Dr Carty was to note in his testimony tabled at the hearing: I have received a considerable number of calls, e-mails and letters from the concerned public about the decision on the Office and I want to publicly acknowledge this support both from Canadians and international partners alike. They all agreed that this has potential to tarnish our image as a leading player in S&T. The fact that we have received such support only serves to underscore the need for a closer look at how we design our science governance system as new issues emerge that will require sound scientific input. We can certainly learn from elsewhere while keeping in mind our own national specificities. Most importantly, this exploration needs to be done in an open and consultative fashion (Carty, 2008).

Quebec experience today

As stated earlier, provinces have jurisdiction over education, higher education and healthcare in the Canadian parliamentary system. Successive Quebec governments have always aimed to protect these rights at the same time as offering mechanisms to ensure the leadership of its citizens on the national and international scene. It is with these objectives in mind that in July 2011, Bill 130 created an umbrella organization that would regroup its three research funds under one banner: Fonds de Recherche du Québec—FRQ (regrouping three funds: Nature & Technologies; Health; Society & Culture). The new organization initially received considerable criticism from within the Quebec science community who had argued against the closure of the CST, as well as from others who felt that the appointment of a Chief Science Officer to head the new institution would put him in a conflict of interest position.

The newly appointed Chief Science Officer, Dr Rémi Quirion, had considerable experience both as a respected researcher at McGill University and a former director of a virtual institute with the Canadian Institutes of Health Research. His mandate as Chief Science Officer was to:

- Advise his minister and the government on research and innovation
- Increase the competitiveness of Quebec researchers
- Increase international impact of research
- Foster large intersectorial research programs
- Improve public science literacy
- Promote knowledge mobilization

The position, the first of its kind in Canada at the provincial level, went through some turbulence as provincial elections led up to having the Chief Science Officer reports to up to six Ministers in six different ministries in less than 4.5 years! As an adviser to the government, his remit includes:

- Strategies for R&D in Quebec: intersectorial challenges and opportunities in the Canadian context

- Indirect research costs: comparison between Quebec and Canada
- An open access policy for Quebec in the context of government transparency
- A Quebec policy on research integrity
- Establishing research priorities and niches of excellence for Quebec: learning from international best practices
- Financing large research infrastructure: challenges and opportunities
- An international strategy for the Quebec research funds
- Promotion of science literacy

Further, in the development of a 5-year research and innovation plan (PNRI—to be updated by the newly created Minister of Economy, Science and Innovation), to run from 2014 to 2019, the Chief Science Officer had been instrumental in outlining key areas such as advising the government of the urgent need to make choices, to focus on niches of excellence and a few large projects related to major challenges of society. In addition, he advocated for the government to invest significantly (3% target of Gross Domestic Expenditures on Research and Development (GERD) to GDP) and for the long term. Several principles have guided the choice of priority areas including

- Balance between all types of research, whether in basic science or applied research, in public or private sectors
- Emphasis on intersectorial research, with a special focus on major societal challenges and domains of excellence
- The importance of close collaboration between all stakeholders in the knowledge ecosystem
- International leadership

The Chief Science Officer called upon the broad Quebec scientific community to help identify major societal challenges. Three were identified as major priorities for Quebec:

- Demographic change and immigration (how to adapt the organization of society as it ages—for example, first years of life, culture and well-being, home care, dementia) as well research related to terrorism and radicalisation
- Sustainable development (better balance between human beings and their environment; for example, climate change, energy choices, mobility and modes of transportation, lifestyles; consortia in the field of electric transportation including the smart grid, product life cycle, the North, an ambitious maritime strategy, Future Earth)
- Entrepreneurship and creativity aiming at Small and Medium-Sized Enterprises (SMEs)
- Moreover, seven niche of excellence were identified namely: Aerospace/Food Industry/Biotechnologies/Clean energy/ Creative Industries/Personalized medicine/ITC

With the most recent ministerial reorganization (January 2016) and the creation of the Ministry of Economy, Science and Innovation, it is expected that the Chief Science Officer will be actively involved in updating Quebec's research and innovation strategy as well as its broad digital one, as the latter is placed under the leadership of his minister.

Quebec's Chief Science Officer, like the NSA had done in 2005, also examined how science advice operates elsewhere and held a meeting in June 2014 in Montreal inviting several guests from around the globe to speak to their experience. This preceded an excellent international conference on science advice held in Auckland in August 2014 hosted by the New Zealand Chief Science Adviser. It led to the creation of INGSA with Quebec's Chief Science Officer being part of a small executive committee. The next international conference of that type will be held in Brussels in September 2016, while smaller workshops aiming at increasing global capacity in science policy are being held or planned over the next few years, including French and English workshops on the African continent.

At the end of his first 5-year term, what can be concluded on the impact of the creation of such a high-level position in Quebec? Certainly, improved visibility for science and science advices in government, especially with elected officials who often call upon the Chief Science Officer for opinions and advice ranging from radicalization to climate change and genomics. Moreover, considering the long established leaderships of the main three funding councils in supporting academic research in Quebec, the decision to appoint the Chief Science Officer as head of these councils was certainly justified to limit the existence of too often seen silos between various government departments and its multiple priorities. Of course, this is often a delicate balancing act but this somewhat unique model seems to work for Quebec and insures more coordinated approaches towards research and innovation for the province. It will now be interesting to see the type of partnerships that will be developed with the upcoming appointment of Canada's NSA.

A new direction and lessons learned

With all of this experimentation in science advice within Canada over the years, there are some general lessons that can be applied. The first lesson to bear in mind is that the policy question should be clearly delineated.

Science advice requires several key ingredients if it is to have effective impact:

- A recipient
- Timeliness
- Relevancy
- Trust, personal relationships and integrity
- Sound communication between advisers and decision makers

As several commentators at the Auckland global science advisors meeting in 2014 noted, some of the advice will be ignored (after all—it is only advice); some will be taken on board by the clients, and some will be deferred. Advice—in its many forms from secret to open debate and reporting—has an inherent public dimension and will involve various degrees of consultation and cooperation with interested stakeholders. Such consultations can shed greater light on an emerging area of economic-social interest to the country; in other cases, the public consultation can be designed to help frame an issue that is poorly defined for public policy action; and in still others, the matter is merely a case of getting better data or evidence to influence agendas of one sort or other. Increasingly, science advice is called upon to deal with emergencies and crisis.

The second matter at hand should be—why is this science advisory body best placed to undertake the advice? One would be surprised at the number of studies that have been commissioned on various policy issues without taking into account that existing structures can already do this work. At times, this is because the sitting government may actually wish to show that it is taking a fresh approach, hence the proclivity to go to a new source instead of relying on existing machinery. In Canada, this may have reached pathological levels as the pace of institutional creation is outstripping the capacity to learn from past experience. But such churning is perhaps the consequence of a winner take all political system.

A third consideration centres on the receptivity of the advice. Will this have an audience? Can it make a difference? Are the recommendations crafted in such a way as to be realistic in the current political context? This is not to suggest that advice cannot

be far-reaching and bold in its direction. Rather, it must be conscious of its environment to ensure a better grafting of the advice to the body politic and the public it purports to represent.

Fourth, and this is often the most important, what legacy is built into the advice? Much advice is geared to the here and now, and quite often with good reason—advice needs to be timely (for example, food scares, pandemics, safety recalls). But if well delivered, it should have a foresight dimension and be reflective of down-stream impacts and needs.

And as New Zealand's Chief Science Advisor, Gluckman reminds us, we need to understand that science informed policy-making needs both informal and formal inputs; these operate very differently and for very different reasons and a complete advisory system needs both approaches. Until relatively recently, the nature of science advice to government was limited to relatively technical advice on relatively linear issues regarding government's use of science say in managing fish stocks or on adopting new health technologies. In many ways these are technological rather than scientific challenges and, with some caveats, they are not the cause of the challenges we face at the interface between science and policy. Rather, now we face a very different set of challenges, particularly the so-called "grand societal challenges", which span borders, disciplines and comprise a constellation of related and compounding questions (Gluckman, 2014b).

Learning is important in this context.

For instance, can this advice also help develop a new generation of talent and skills that can further advance the recommendations and their outcomes beyond the lifespan of any given government? The best advice should be context driven to its audience, but generational in its impact. Already, a Science Advice Workshop for African Scientists took place in South Africa, March 2016, and as mentioned earlier, a French-speaking initiative is in the works for 2017 in Dakar (Senegal). For all of these reasons, it would seem relevant to explore the creation of well-articulated, international training programs focusing on these issues.

Finally, the advice in question needs to be truly democratic in nature. Far too much advice funded by public sources ends up private or confidential with little interest in sharing the analysis and the results to larger audiences.

One should not forget that the credibility of the research and knowledge communities is at stake in this process. And communicating the advice in a literate fashion is equally critical. If you can't say what you have to say for the general public, then the message is lost. Without open and clear communication, the public becomes increasingly suspicious of the nature of any advice, including that emanating from scientists. Decision-making can suffer as a consequence (Achenbach, 2015).

To return to Canada's experience, it is instructive to recall that the country had a National Forum of Science and Technology Advisory Councils that met regularly to compare good practices and to work together on issues of common concern. This was during the heyday of Canada's first and only national Science and Technology Policy signed in 1987 by all levels of government—provincial, territorial and federal. Along with the SCC and NABST, the other advisory councils on S&T are shown in Table 6.

The point is that governments of all stripes in 1987 felt a need for sound advisory structures, along with a pan-Canadian dialogue to come together on challenges and opportunities. As Mr Frank Oberle, the federal Minister of State for Science and Technology at the time (1986) puts it: *If European nations have found it necessary to join their efforts in order to use S&T to maintain prosperity, it seems that our ten provinces and two territories, and a federal government, must also see the need to join efforts.*

Table 6 | Advisory councils on S&T

Province-territory	*1987–2014*	*2015*
Alberta	Premier's Advisory Council on Health	No replacement—Alberta relies on an external advisory council, when needed
British Columbia	Premier's Advisory Council on Science and Technology	Replaced by* Premier's Technology Council (2001)
Manitoba	The Economic Innovation and Technology Council	The Council was terminated in 2014 with no replacement
New Brunswick	Minister's Advisory Board on Science and Technology	No replacement
Newfoundland and Labrador	Science and Technology Advisory Council	No replacement
Northwest Territories	Science Institute of the Northwest Territories	—
Nova Scotia	Council of Applied Science and Technology (no replacement)	Replaced by the† Aurora Research Institute (by virtue of the Aurora College Act created in 1988)
Ontario	Premier's Council on Economic Renewal	No replacement
PEI	Advisory Council on Science and Technology	No replacement
Quebec	Conseil de la science et de la technologie	It was replaced by the creation of the position of‡ Chief Scientist in 2011
Saskatchewan	Advisory Council on Science, Technology and Innovation then Economic Diversification Council	The Council was replaced by§ Innovation Saskatchewan, created in 2009
Yukon	Yukon Science Institute	The Institute was replaced by the‖ Office of the Science Adviser of the Executive Council Office

*http://www.gov.bc.ca/premier/technology_council/.
†http://nwtresearch.com/about-us/nwt-research-policies/nwt-science-agenda.
‡http://www.frq.gouv.qc.ca/en/chief-scientist/biographical-notes.
§http://www.innovationsask.ca.
‖http://www.eco.gov.yk.ca/science/index.html.

Conclusion

An inevitable conclusion from this brief documentary history is that science and science advisory systems in Canada have come and gone on a whim and have rarely had the stability and support to make a lasting contribution to science policy. As an example, over the last decade 2004–2014, Canada has gone from having an NSA, Chief Scientists in many government departments, and an Advisory Body CSTA, which authored a wise set of principles for science advice to government (the SAGE report), closely similar to those now embedded in the United Kingdom, New Zealand and Japan, to virtually nothing! There is still a STIC but it does not report publicly, is not independent and takes its direction from the government.

However, with the election of a federal Liberal government in late 2015, a new Minister for Science, Dr Kristy Duncan, has been appointed. The remit of this new Minister includes creating the position of a Chief Science Officer mandated 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. Various organizations have also been established in Canada designed to help improve the ability of governments to use evidence more effectively in decision-making. Evidence for Democracy and the Science Integrity Project are two such examples. Some learning has been gleaned from the various experiments. Knowledge will continue to be the currency of public policy, and new ways to insert sound science advice into this ever expanding landscape are essential.

There is a strong and convincing case to be made for a permanent science advisory structure in Canadian governments (at both the federal and provincial levels) that can add light to what has been at times a sombre debate. A more robust system with the ability to overcome challenges and stay intact, in the face of political change, is needed. Too often a change of government and political philosophy in Canada has led to the wholesale abandonment of advisory boards, councils and committees, inevitably compromising the entire science advisory process and ultimately requiring a rebuild, usually under a new political regime. Such "dislocations" are expensive both in terms of the overall costs of shutdown and restart but also due to the real loss of expertise in the process.

Another deleterious impact of the "create and destroy" mentality of successive governments is that the stability, longevity and perceived effectiveness of a system help to build trust and legitimacy in the public eye.

Although governments will often cite the desire to reduce costs as a reason for eliminating advisory boards, the more fundamental issue is a failure to recognize the pervasiveness of science and technology, its profound impact on economies and societies and the critical need to consider scientific evidence as a crucial element of public policy. In the Canadian Federation of 10 provinces, three territories and a federal government, there is a very special role for the crown to take a leadership role in both defining policy for science and also ensuring that science advice is integral to government decisions that serve Canada's strategic interests in innovation, wealth creation, public health, environmental protection and natural resource exploitation. With the notable exception of Quebec, which has its own Chief Science Officer and unique structure for incorporating science advice in decision making, the provinces have generally not set up their own science advisory systems and Federal-Provincial integration has not been a major issue.

Over the past decade, more and more governments have come to recognize the need for science advisors and science advisory systems to provide pertinent and timely scientific evidence to inform policy and decision makers. We can only hope that Canada will be prepared to join this global movement in a more effective way.

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Data availability

Data availability not applicable to this article as no datasets were generated or analysed.

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