

SAC Subcommittee on
S&T Research Methods

Assessing Research and Innovation Performance in Canada

The Council of Canadian Academies

The Council of Canadian Academies (CCA) is a not-for-profit organization that supports independent, science-based, authoritative expert assessments to inform public policy development in Canada. Led by a Board of Directors and advised by a Scientific Advisory Committee, the CCA's work encompasses a broad definition of science, incorporating the natural, social, and health sciences as well as engineering and the humanities. CCA assessments are conducted by independent, multidisciplinary panels of experts from across Canada and abroad. Assessments strive to identify emerging issues, gaps in knowledge, Canadian strengths, and international trends and practices. Upon completion, assessments provide government decision-makers, researchers, and stakeholders with high-quality information required to develop informed and innovative public policy. All CCA assessments undergo a formal peer review and are published and made available to the public free of charge. Assessments can be referred to the CCA by foundations, non-governmental organizations, the private sector, and any level of government.

www.cca-reports.ca

 [@cca_reports](https://twitter.com/cca_reports)

SAC Subcommittee on Science and Technology Research Methods

The CCA's [Scientific Advisory Committee](#) (SAC) formed a S&T Methods Subcommittee to examine the challenges and limitations of methods used to assess Canada's strengths in science and technology (S&T) and research and development (R&D). The subcommittee's recommendations help to inform the assessments that CCA undertakes in this area.

The CCA has been documenting Canada's S&T and R&D strengths and weaknesses in a series of reports dating back to 2006. The most recent, *Competing in a Global Innovation Economy: The Current State of R&D in Canada*, was released in April 2018. The report identified various data limitations that inhibit the assessment of R&D activity and excellence in Canada. This is particularly the case with industrial R&D and research in the social sciences, arts, and humanities. The data available on industrial R&D activity continue to paint an incomplete picture of private sector investment in innovation, and suffer from time lags for some measures, such as internationally comparable data on R&D intensity. In the social sciences, arts, and humanities, standard bibliometric indicators are less informative because these disciplines prioritize other types of research outputs beyond standard journal articles.

The subcommittee was established to find potential solutions to these and other challenges. Its mandate was to explore the methodologies available for assessing Canada's S&T and R&D strengths and activities and to identify improved methodologies that may address limitations documented in past assessments.

The subcommittee was convened in April 2019 and presented its findings to SAC in November 2019. Members included:

[Eliot A. Philipson](#), O.C., FCAHS (Past Chair)

[E. Louise Earl](#)

[Kaye Husbands Fealing](#)

[Barbara Neis](#), C.M., FRSC

[Nicole Poirier](#), FCAE

Contents

- 01** Introduction
- 02** Bibliometrics
- 03** HASS Disciplines
- 04** Opinion Surveys
- 06** Major Science Infrastructure
- 06** Industrial R&D
- 08** Innovation
- 10** Full Report

Introduction

Since 2006, the Council of Canadian Academies (CCA) has produced a series of reports that document Canada's strengths in Science and Technology (S&T), Industrial Research and Development (R&D), and innovation, as determined by comparison with the performance of other countries. Several of these reports highlighted the limitations and weaknesses of the assessment methods and indicators that were used in their analyses. In the expectation that the CCA may be asked to undertake similar assessments in the future, the CCA's Scientific Advisory Committee (SAC), with the support of Management and the Board of Directors, struck a subcommittee of SAC to address the methodologic challenges identified in the previous reports and recommend potential solutions. The intent of these recommendations was to inform future expert panels, but not to bind them to any particular approach.

Mandate

The mandate of the Subcommittee was to explore in depth potential solutions to the challenges of assessing Canada's S&T, R&D, and Innovation strengths; to identify new and emerging methodologies to address these challenges; and to provide recommendations for future assessments that may be undertaken.

In particular, the scope of the Subcommittee's mandate included the following:

- Consideration of weaknesses in existing bibliometric methods and indicators, and any new methodologies that may address these weaknesses.
- Challenges in assessing research activity and strengths in the social sciences, humanities, and arts; and new approaches to address these challenges.
- The role of opinion surveys in assessing S&T and R&D strengths.
- Challenges in assessing Canada's industrial R&D outputs, outcomes, and impact; Canada's innovation performance; and new or promising approaches to address these challenges.
- The optimal charge and scope of future assessments of Canada's strengths in S&T, R&D, and Innovation.

Research Methods and Subcommittee Meetings

The Subcommittee engaged in three types of evidence gathering initiatives:

- A detailed review of the literature by CCA staff.
- A call for evidence that was sent to 49 targeted stakeholder organizations and individual experts across Canada and internationally.
- Focused interviews with experts and stakeholders on specific components of the Subcommittee's mandate.

The Subcommittee met 13 times between May, 2019 and October, 2021. With one exception, all meetings were held by videoconferencing (Zoom). During these meetings:

- Seventeen separate organizations (some represented by 2-3 individuals) and individual experts were interviewed in depth.
- The Subcommittee discussed several relevant papers and reports identified by staff and Subcommittee members, as well as the responses received to the Call for Evidence.
- Conclusions and recommendations were formulated.

Bibliometrics

Addressing the Limitations of Bibliometrics

The field of bibliometrics is dynamic. The challenge for future assessment panels will be, on the one hand, to strike a balance between providing continuity with past assessments by using comparable data and indicators, and on the other hand, providing new, novel, and more accurate insights by using emerging indicators and approaches. In doing so, it will be important that CCA assessments be based on metrics that are used by other countries so that international comparisons can be made.

Key Findings and Recommendations

In consideration of the limitations of bibliometrics and possible approaches to address them, the Subcommittee came to the following conclusions:

1.

In contrast to the natural sciences, engineering, and health sciences, bibliometrics capture only a small fraction of the full range of outputs in the humanities, arts, and social sciences (HASS disciplines), and therefore are insufficient in assessing the strengths of these disciplines.

2.

A hybrid algorithmic approach provides a promising solution to the challenge of assigning individual research papers to their most appropriate scientific field and subfield. In this system, the taxonomy of fields and subfields is still pre-determined, as in the Scopus and Web of Science systems. However individual articles are assigned to these fields and subfields based on the article's key words, rather than on the journal in which it is published. This approach is computationally intensive but should be considered for future CCA assessments. Depending on the resources required, it could be simultaneously compared with the traditional approach used in previous assessments in which field and subfield assignments were based solely on the specific journal in which the work was published and not on the scientific nature of the research.

3. Defining an approach to assignment of research fields and subfields that does justice to interdisciplinary work remains a challenge. However, there are new options that future panels should consider, foremost among these being the hybrid algorithmic approach. Dedicated, topic or theme-specific bibliometric analyses should also be considered to identify multidisciplinary research publications in specific domains that cut across the traditional fields and subfields of research classification.

4. New indicators for measuring research impact should be explored for future assessments. Foremost among these is the Relative Integration Score that is based on the full distribution of citations by decile, in contrast to the Average Relative Citation (ARC) or Median Relative Citation (MRC) indices which are affected by the typically skewed distribution of citations in any given field or subfield.

5. Future CCA panels should consider exploring and highlighting in greater detail the extensive subfield data generated by bibliometric analysis to provide a more granular, and therefore more useful, identification of Canada's S&T strengths.

HASS Disciplines

Measuring the Research Performance in the Humanities, Arts, and Social Sciences

The fundamental challenge of identifying Canada's research strengths in the HASS disciplines using international benchmarks is that the one instrument capable of such an assessment – traditional bibliometric indicators – reflects only minor fraction (peer-reviewed papers in scholarly journals) of the research output and impact of these disciplines. In contrast, approaches that are more inclusive of the broader output and impact, such as a full portfolio assessment and informed expert review, are not only resource intensive, but have not yet been scaled up to an international, or even national level.

Key Findings and Recommendations

This challenge, while formidable, is not entirely insurmountable. Several promising developments that are in the pipeline warrant attention by future expert panels, particularly the following:

1. Standard bibliometric databases, such as Web of Science and Scopus, are expanding the number of scholarly journals in the HASS disciplines that are included in their databases. In addition, peer-reviewed books and book chapters are rapidly being incorporated into these databases, thereby adding a major class of outputs of HASS scholarship that has been previously lacking.

2.

Newer databases, such as Google Scholar, provide more extensive coverage of diverse outputs in the HASS disciplines than do Web of Science or Scopus. Altmetrics could also provide additional insights on research outputs and impact in the HASS disciplines; however, the heterogeneity of altmetrics and issues related to data quality and reliability would need to be carefully considered.

3.

Standardized research reporting systems that incorporate more comprehensive data, including socio-economic objectives, are under development, including the new Canadian Research and Development Classification System. This system will facilitate aggregate analysis of research outputs at the national level, by field and subfield. It may also facilitate some level of international comparisons, given its compatibility with the field taxonomy used by the OECD.

4.

In contrast to other disciplines, bibliometric indicators alone are insufficient for evaluation of the impact of research in the HASS disciplines, which require a combination of quantitative and qualitative approaches, such as that outlined in the Impact Framework of the Canadian Federation for the Humanities and Social Sciences. Given these differences, the HASS disciplines may be better served in future CCA evaluations by a separate expert panel familiar with the most appropriate HASS evaluation methods.

Opinion Surveys

The Use of Opinion Surveys in CCA Assessments

Opinion surveys have played an important role in previous CCA assessments of the strength of S&T and R&D in Canada, in comparison to other countries. However, concerns have been expressed about expert opinion surveys in this context, related to the reliability of expert opinion and to sample sizes. Opinion survey data (like all data) has limitations, but it also has the potential to enhance understanding of the S&T landscape by collecting evidence on domestic and international perceptions regarding Canada's research strengths and weaknesses.

Key Findings and Recommendations

The Subcommittee recommends that the CCA continue to use opinion surveys to gather complementary data that can be integrated with other metrics. The Subcommittee also recommends that future expert panels consider the following possible approaches to opinion surveys:

1.

It may be possible for future expert panels to access data from international academic reputation surveys such as those carried out by Times Higher Education (THE) and Quacquarelli Symonds (QS). These surveys are widely followed and influential. The use of large-scale survey data in these rankings, and its integration with other metrics, offers lessons for CCA panels. Furthermore, THE and QS may also allow CCA panels access to data from core questions in their surveys, thereby enabling CCA to generate international comparisons and insights without administration of a new, stand-alone survey. Access to such data would also address the perception that respondents to a CCA-sponsored survey are more likely to report overly positive views regarding Canada.

2.

International surveys should prioritize simplicity and response time in design, and anticipate how cultural differences could affect responses. Past CCA international surveys featured simple, easy to understand questions and were quick to complete. They are comparable to other large-scale international surveys in this respect. Future panels should continue to aim for similar benchmarks, keeping response times at 5 minutes or less. Survey field testing should be used to assess response patterns, identify problem areas, and generally track respondent behaviour to identify/resolve challenges.

3.

Future panels might consider whether questions focused on identifying *institutions* rather than *countries* would result in more useful and valid responses, and potentially provide respondents a more intuitive and accessible way to identify leading centres of research in their fields. Institutional data could then be aggregated upwards to the level of countries.

4.

Future expert panels should consider weighing survey results more heavily for fields where bibliometrics are problematic. Both the THE and QS academic reputation surveys allocate greater weight to survey results for fields such as the arts, humanities, and social sciences where citation-based indicators are problematic.

5.

CCA expert panel reports should clearly articulate both the strengths and limitations of opinion survey data. To address the perception that opinion survey data is more suspect than data from other sources, panels may need to place more emphasis on describing the value of such data while clearly stating its limitations. In addition, expert panels may have to take extra steps to demonstrate that these surveys meet the highest possible standards of methodological rigour.

Major Science Infrastructure

Evaluating Major Science Infrastructure

Major Science Infrastructures (MSI) represent scientific facilities, infrastructure, or programs that are of a size, scope, technological complexity, and cost that place them beyond the capacity of any one university or province to build and maintain. MSI are considered national research facilities, available to researchers across Canada. Most are also international in scope, attracting scientific collaborators, faculty, and students from around the world, thereby enhancing Canada's international scientific reputation.

Previous CCA assessments of Canada's strengths in S&T did not include any formal evaluation of Canada's MSI in comparison to those of other countries. However, these assessments noted that on surveys of both Canadian and international experts, several of Canada's MSI facilities were mentioned as distinct advantages for Canada.

Key Findings and Recommendations

The Subcommittee examined the feasibility of formally evaluating Canada's MSI in future CCA assessments and notes the following observations:

1.

Currently there is no international index or data set that would allow a quantitative comparison of MSIs on a country-by-country basis. In recent years, however, the performance evaluation of MSIs in many countries, including Canada, has evolved to the point that there is considerable alignment on the core or key performance indicators by which MSI performance should be assessed.

2.

Given these developments, it is recommended that future expert panels review further developments in this field to determine the feasibility of including an assessment of Canada's MSI strengths in comparison to those of other countries.

Industrial Research and Development

Assessing Industrial R&D in Canada

CCA expert panels have struggled with several methodological challenges related to assessing industrial R&D performance in Canada. There is a general lack of high-quality, broadly applicable data on industrial R&D outcomes and impacts. Patents and related data (i.e., technometrics) are often used as a measure of industrial R&D outputs, but the interpretation of patent-based indicators can be problematic. Data for other measures of outputs or impacts (e.g., startups, invention disclosures, patent

licenses) is often available in isolated cases, but rarely on a scale that supports international comparisons.

Forced to focus primarily on inputs, past panels have relied heavily on industrial R&D expenditures and related variables. In these cases, long lag times for some internationally comparable measures (especially R&D intensities by industry) have limited the usefulness of the data. In addition, existing classification systems for data collection and reporting have made it difficult to interpret the significance of R&D activity in some industries. As a result of these challenges, CCA expert panels have generally been less confident in their ability to assess Canada’s industrial R&D strengths than its academic research strengths.

The main hindrance to past expert panels in assessing industrial R&D strengths in Canada has been a lack of datasets with sufficiently broad international and intersectoral coverage to support the type of comparisons needed to identify Canada’s areas of relative strength. Although this is still likely to be the case (outside of patent databases), several recent advances at Statistics Canada should yield significant benefits in this context. Firm-level datasets also offer alternatives. A combination of analysis of larger firms with major R&D expenditures, together with assessment of startup activity through a database like Crunchbase could overcome some of the limitations of traditional data sources on R&D spending, providing more nuanced insights into how Canada’s industrial R&D landscape is evolving.

Key Findings and Recommendations

Given the limitations faced by previous expert panels in assessing R&D strengths in Canada, the Subcommittee noted the following:

1.

Traditional data sources, such as Statistics Canada’s R&D data, are improving, considerably mitigating past challenges. These improvements include the timeliness of many indicators and new data on R&D within specific industries that were problematic in the past.

2.

Firm-level datasets and analytical approaches may offer benefits over standard comparisons of national industrial R&D expenditures. Identifying a set of global R&D leaders/performers based on public financial and R&D data, and characterizing Canada’s presence and role within that pool of firms, may be instructive in identifying specific areas of industrial R&D activity and excellence in Canada. These kinds of approaches are used in the EU Industrial R&D Investment Scoreboard.

3. Crunchbase is an emerging source of data on VC-backed startups that could be very useful for both tracking Canadian trends among emerging technology firms, and in making international comparisons. This data set is being used increasingly by innovation/R&D scholars and international organizations such as the OECD.

4. Linked bibliographic databases such as Dimensions are increasingly tracking information that connects research grants with outputs and outcomes. These databases should be explored as a potential source of information that draws links between research funding and outcomes, and impacts of interest, including publications, patents, and other variables.

5. Based on interviews undertaken by the Subcommittee, some key economic measures have been underutilized by past CCA panels, including the proportion of public vs private firms in Canada that invest in R&D, comparisons of R&D activities based on firm size, and other measures. These indicators add insights beyond traditional R&D metrics and help understand the commercial context for business R&D investment in Canada.

Innovation

Assessing Innovation in Canada

Apart from the 2009 report on Business Innovation, CCA expert panels have not been directly asked to assess innovation in Canada. However, the S&T/R&D panels of 2012/13 and 2018 were charged with identifying the barriers impeding the translation of Canada's research strengths into innovation and wealth creation. These Panels endeavored to document Canada's innovation performance and the linkages between research, technology development, innovation, and economic outcomes. They reported on the evidence available, including innovation survey data, measures of R&D outputs such as intellectual property, measures of investment (e.g., venture capital), measures of entrepreneurship (business startups), and economic measures such as productivity indicators, GDP growth, and trade flows.

These panels, however, were able to report only minimally on Canada's innovation performance in comparison to that of other countries. This problem relates to the fact that there is no single metric or even a set of metrics that accurately quantifies the level of innovation taking place in a business organization, much less in a country, nor is there a common unit of measure for innovation.

The development of comprehensive, useful measures of innovation remains an active area of research that could enrich the methodological options available to future panels. For example, a SSHRC-sponsored research network, the Partnership for the Organisation of Innovation and New Technologies

(4POINT0), is developing new metrics and indicators that better reflect innovation within an ecosystem environment. A group of Canadian research and technology organizations is also exploring these issues as members of Innoventures Canada (I-CAN), with an ongoing initiative to identify new measures, building on work from the European Association of Research and Technology Organizations (EARTO). These collaborations will continue to expand the number of datasets, indicators, and associated resources available to future CCA expert panels. The development of datasets with full international and intersectoral coverage, however, is likely to be slow, given the intensive time resource requirements and coordination challenges for assembling such large data sources.

In addition to technological and business innovation, the Subcommittee also considered the extent to which future panels could provide a more in-depth exploration of social and inclusive innovation. The 2018 panel had noted that this was an important area of ongoing research, but that there was a lack of systematic data on social and inclusive innovation. In general, this remains the case and few resources exist that allow for broad comparisons across multiple jurisdictions; however, several initiatives are underway to develop conceptual frameworks and datasets supporting international comparisons of social and inclusive innovation.

Key Findings and Recommendations

Future CCA panels will be guided by their charge in the degree to which they assess Canada’s overall innovation performance. Given extensive discussions in previous CCA reports and other documents, it may be more productive if future assessments are guided by a different question rather than another re-examination of barriers impeding the translation of R&D into innovation and wealth creation.

To the extent that future CCA panels are asked to investigate and assess the state of innovation in Canada, the Subcommittee offers the following recommendations:

1. Future panels should carefully investigate new Canadian efforts to develop indicators of innovation ecosystem function and health, including the efforts underway at 4POINT0 and I-CAN. Statistics Canada is also in the process of reassessing its suite of indicators with a focus on the entire science, technology, and innovation ecosystem.
2. A detailed conceptual framework of innovation could support more nuanced discussion and lead to more impactful conclusions. Frameworks that better account for the diversity of types of innovation (whether by industry or sector, by for-profit or not-for-profit entities, by market, by stage of growth, or by the nature of the product or process developed) would likely lead to more insights. This may also help ensure that the distinctions between industrial R&D and innovation continue to be acknowledged.

3.

International rankings/assessments such as the Global Innovation 1000 and the Global Innovation Index could be useful sources of data and analysis. These efforts provide data from many countries for a variety of indicators, covering both innovation inputs and outputs. Panels could well use this data as a basis for their own assessments, focusing on Canada's relative strengths and weaknesses and developing more detailed analyses as needed, based on the higher-level findings and trends.

4.

The CCA can provide leadership in accepting the challenge of assessing social and inclusive innovation. Data resources regarding such innovation remain limited for documenting national trends and making international comparisons, but new approaches are being explored that future panels should consider. Even in the absence of such data, however, future panels can add value by offering a more extended and nuanced discussion of these topics, highlighting the inequalities that can result from different types of innovation, and what is known about promising strategies for ensuring that innovation and its benefits are not limited to particular groups.

Full Report

For the full report on *Assessing Research and Innovation Performance in Canada*, or to receive the reference list, please email us at info@cca-reports.ca.