



INFORMING RESEARCH CHOICES: INDICATORS AND JUDGMENT

Executive Summary



Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

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Discovery research in the natural sciences and engineering (NSE) is a key driver in the creation of many public goods. Scientific advances help catalyze innovation, create new knowledge, foster economic prosperity, improve public health, enable better protection of the environment, strengthen national security and defence, and contribute in myriad other ways to national and sub-national policy objectives. For all of these reasons, most governments around the world wisely invest substantial public resources in supporting discovery research in the NSE. Canada is no exception. The Natural Sciences and Engineering Research Council (NSERC) spends approximately one billion dollars a year on scientific research. Over one-third of that goes directly to support discovery research through its Discovery Grants Program (DGP). Many influential Canadian discoveries and research breakthroughs stand as testimony to the value of these investments, and past evaluations of the DGP have found it to be a vital and highly effective component of Canada's research funding landscape.

Public funding organizations like NSERC often struggle with how best to allocate funding across research fields and programs. Once these allocation decisions are made, funding organizations must then determine how to best communicate and justify them to the research community, policy-makers, and the public at large. Thus funding organizations are increasingly looking to science assessment tools and quantitative science indicators for guidance in informing these decisions. New indicators and an emerging "science of science policy" can potentially improve the overall effectiveness and transparency of how funding agencies allocate resources and monitor the performance of their research investments. The growing abundance of indicator and assessment choices, however, can also make it difficult for policy-makers and research funders to know which assessment methods and indicators are most appropriate in a given context.

THE CHARGE TO THE PANEL

To help guide future funding reallocations for the DGP, in 2010 the federal Minister of Industry, on behalf of NSERC, posed the following question to the Council of Canadian Academies (the Council):

What do the scientific evidence and the approaches used by other funding agencies globally have to offer, in terms of performance indicators and related best practices in the context of research in the natural sciences and engineering, carried out at universities, colleges, and polytechnics?

In response to the charge, the Council convened an Expert Panel of 16 Canadian and international experts from diverse fields such as public policy, economics, research funding and administration, mathematics and statistics, science history and sociology, bibliometrics, and other NSE fields. The Panel, which met four times over the course of 2011, reviewed a wide range of evidence from published studies and examined science assessment practices in 10 countries in detail.

SCIENCE INDICATORS AND ASSESSMENT STRATEGIES FOR DISCOVERY RESEARCH

Existing science indicators and assessment strategies can be categorized in many different ways. They include those based on deliberative methods, such as peer or expert review, and those based on quantitative indicators, including publication and citation counts, numbers of researchers or students, research funding amounts, and grant applications. NSE research funding allocation decisions require sets of indicators that capture information on research quality, research trends, and research capacity.

For each of these assessment types, the Panel developed a taxonomy of potential methodologies and indicators, and assessed the validity of these indicators with respect to the assessment objective. The Panel focused exclusively on science performance at the national level of research fields in the NSE (rather than at the level of individual scientists or research teams), and on the indicators and methodologies most relevant to discovery research, such as that funded by NSERC's DGP.

MAIN FINDINGS

Many science indicators and assessment approaches are sufficiently robust to be used to assess science performance in the NSE at the level of nationally aggregated fields. For example, bibliometric indicators based on weighted publication counts can be useful in assessing research output at the level of a research field. Citation-based indicators — when appropriately normalized by the field of research and based on a sufficiently long citation window — can be useful metrics in assessing the overall scientific impact of research in a given field at the national level. Many other types of quantitative indicators, such as those based on student or researcher population, research funding amounts, and the state and quality of available scientific infrastructure and equipment, can be useful in characterizing research trends or national research capacity in certain assessment contexts.

Quantitative indicators should be used to inform rather than replace expert judgment in the context of science assessment for research funding allocation. Although many types of quantitative indicators can be reliable and informative in science assessments at the national field level, these indicators should not be used to support research funding allocation without expert judgment. The body of evidence now available recognizes that the most promising strategies rely on a balanced use of quantitative indicators and expert judgment. A review of recent experiences in selected countries and research funding organizations globally lends further support to this conclusion. In the United Kingdom, the long-standing Research Assessment Exercise (RAE) is scheduled to be replaced with the Research Excellence Framework (REF). The REF will retain core reliance on peer review, but will allow for use of quantitative indicators. In Australia, a recently adopted national research assessment system relies on a model of expert judgment informed by quantitative indicators. Many countries — including the United States, Finland, and the Netherlands — have employed science assessment strategies combining indicators and expert judgment in various contexts. For national research assessment in the NSE at the field level, the weight of the evidence suggests the best approach is a combination of quantitative data and expert judgment.

International “best practices” offer limited insight with respect to science indicator use and assessment strategies. Construction and application of indicators are context dependent. Whether an indicator is informative or reliable depends as much on the specific context as on the nature and construction of the indicator. No single indicator, set of indicators, or assessment strategy offers an ideal solution in research assessment contexts for NSE discovery research. The individual circumstances of the assessment and the research funding context must be considered. For NSERC, these decisions will necessarily take into account both the overarching federal S&T strategy as well as the mandate of NSERC and the specific objectives of its programs. The assessment must reflect proximal goals (in terms of desired outcomes or results) and the ultimate objectives of the funding program or organization.

Mapping research funding allocation directly to quantitative indicators is far too simplistic, and is not a realistic strategy. Indicators may reveal useful information about science performance, but funding allocation decisions are complex. In most respects, neither the existing body of evidence nor the experience of international funding processes justifies a simplistic funding allocation based solely on quantitative indicators. Funding agencies may choose to increase the allocation of resources to an area of research weakness to bolster performance, or,

alternatively, direct resources away from areas of research weakness and towards strengths. These choices are driven by the strategy of a funding agency and program. In addition, for discovery research, past performance is not always a strong predictor of future performance. In most areas of scientific work, there is no compelling reason to believe that past successes will inevitably lead to future successes or past failures to future failures. As a result, science indicators — essentially measures of past performance — may not provide a reliable guide to future prospects. Overall, the Panel found no evidence that there is a single correct funding response to any assessment results.

GUIDELINES AND PRINCIPLES FOR SCIENCE ASSESSMENT

It was not the Panel's mandate to provide policy recommendations for national NSE assessment strategies. It did, however, formulate some general guidelines for developing an approach to assessments, which are presented here (see Summary of Methodological Guidelines). In addition to methodological guidelines, the Panel developed the following general principles for defining a process for NSE assessment in the context of informing research funding allocation:

- **Context matters:** Effective use of indicators or assessment strategies, as applied to research fields in the NSE, is context dependent. Thus any approach should take into account national science and technology objectives as well as the goals and priorities of the organization and funding program.
- **Do no harm:** Attempts to link funding allocation directly to specific indicators have the potential to lead to unintended consequences with negative impacts on the research community. Promising strategies identified by the Panel to mitigate this risk include relying on a balanced set of indicators and expert judgment in the assessment process.
- **Transparency is critical:** Assessment methods and indicators are most effective when fully transparent to the scientific community. Such transparency should include both the assessment methods or indicators (e.g., indicator construction and validation, data sources, criteria, procedures for selecting expert reviewers) and the method or process by which the indicators or assessments inform or influence funding decisions.
- **The judgment of scientific experts remains invaluable:** Many quantitative indicators are capable of providing useful information in the assessment of discovery research at the national and field level. In the context of informing research funding decisions, however, quantitative indicators are best interpreted by scientific experts with detailed knowledge and experience in the relevant fields of research, and a deep and nuanced understanding of the research funding contexts in question, and the scientific issues, problems, questions, and opportunities at stake.

Summary of Methodological Guidelines

Context is critical in determining whether any science indicator or assessment strategy is appropriate and informative. As a result, it is impossible to provide a list of universally applicable best practices. With respect to assessing scientific research in the NSE at the level of nationally aggregated research fields, however, the following general methodological guidelines may be of assistance.

Assessments of Research Quality

Indicators associated with monitoring research quality often relate to different aspects of quality or different timeframes. As a result, the best approach relies on a combination of assessment strategies and indicators.

- For an assessment of research quality of a field at the national level, a balanced combination of deliberative methods and quantitative indicators is the strongest approach.
- For an assessment of the scientific impact of research in a field at the national level, indicators based on relative, field-normalized citations (e.g., average relative citations) offer the best available metrics. At this level of aggregation, when appropriately normalized by field and based on a sufficiently long citation window, these measures provide a defensible and informative assessment of the impacts of past research in the NSE.
- Quantitative indicators of research quality should always be evaluated by informed expert review because accurate interpretation of data from available indicators can require detailed contextual knowledge of a field.

Assessments of Research Trends

As with research quality, the best approach associated with monitoring research trends relies on multiple assessment strategies and indicators to create a composite perspective on emerging research trends across fields. Such an approach should rely on a combination of assessment strategies and indicators that includes one or more metrics from each of the following types:

- Trends in grant applications by research topic: Capturing research trends that directly pertain to funding requests ensures that trends related to the direct demand for resources across fields are factored into the process.
- Bibliometric methods: Advanced bibliometric approaches based on keyword analysis and identifying emerging clusters of highly cited research provide useful insights at a more detailed level. These can be used to flag active areas of research, which may span multiple fields, as targets for possible added support.

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- **Student population:** Trends in student population, captured by indicators such as PhD enrolment rates by field, can be useful in anticipating longer-term research trends and monitoring changes in the levels of training and expertise over time.

Quantitative indicators of research trends should always be evaluated by informed expert review because accurate interpretation of data from available indicators may require detailed contextual knowledge of a field.

Assessments of Research Capacity

The best approach associated with monitoring research capacity relies on multiple, diverse indicators to create a composite of underlying features that determine capacity in a field. As a general guideline, one or more indicators from each of the following categories is suggested:

- **Funding:** Measures of the level of research funding are informative in analyzing research capacity, particularly in comparison to past funding levels and other research sectors. The diversity of funding sources can also be important.
- **Infrastructure:** The extent and quality of research infrastructure and facilities (e.g., laboratory space, capital investment) are direct determinants of capacity. Measures related to information and communication technology infrastructure should also be considered where appropriate.
- **Numbers of researchers and students:** The student and researcher populations are a key determinant of research capacity, and metrics based on these populations are consequently an important aspect of this type of assessment.
- **Networks and collaborations:** Patterns of research collaboration and networks (e.g., co-authorship of papers) within a field can also be tracked to provide insights into research capacity.
- **Field characteristics:** Assessments of research capacity should also include measures such as the average research team size, average size and duration of research grants, material and equipment intensity, cost of research, and access to research facilities.

As with the assessment of research trends, research capacity in NSE fields should always be assessed through informed expert review because interpretation of data from quantitative indicators may require contextual knowledge.