

Evaluation of NSERC's Discovery Program Final Report

**Findings from the International Review Panel
April 23, 2014**

Table of Contents

1. Introduction	1
2. Findings on Relevance	5
3. Findings on Effectiveness	16
4. Findings on Efficiency	26
5. Conclusions and Recommendations.....	28

Appendix A: Composition of the International Review Committee

Appendix B: Data Available to the International Review Panel

Appendix C: Limitations and Mitigation Strategies

Acronyms

ARC	Average Relative Citation
ARIF	Average Relative Impact Factor
CIHR	Canadian Institutes of Health Research
DAS	Discovery Accelerator Supplements
DG	Discovery Grant
EG	Evaluation Group
GERD	Gross domestic expenditure on research and development
GSC	Grant Selection Committee
HERD	Higher education sector expenditure on R&D
HQP	Highly qualified personnel
NSE	Natural sciences and engineering
NSERC	Natural Sciences and Engineering Research Council
PDF	Postdoctoral fellow
R&D	Research and development
ROI	Return on investment
SSHRC	Social Sciences and Humanities Research Council

1. Introduction

1.1 Evaluation Study

The Natural Sciences and Engineering Research Council (NSERC) has undertaken an evaluation of its Discovery program, which is Canada's main support for broad-based research in the natural sciences and engineering (NSE) disciplines. The study was designed to be compliant with guidelines prepared by the Treasury Board Secretariat of Canada (TBS).

As per NSERC's program alignment architecture, the Discovery program consists of two sub-programs: 1) Discovery Research (of which Discovery Grants is the primary funding opportunity) and 2) Research Equipment and Infrastructure. This evaluation considered research output at the broad program level, but the latter sub-program is very small, it varies in size from year to year, and it was not discussed in detail. Therefore, although the evaluation is intended to cover the broader Discovery program, this evaluation has been scoped such that its primary focus is Discovery Grants (DG).

This assessment is part of NSERC's regular evaluation cycle, whereby grant programs are evaluated every five years to review their relevance and effectiveness. Discovery Grants were evaluated during a similar international review in 2007–08. Based on recommendations of that study, NSERC implemented a number of changes in 2009 and 2010 to improve design and delivery of the program. Two significant modifications are described in section 1.2. NSERC has since been monitoring performance of the peer review process and the impact of the changes.

To conduct this evaluation, NSERC struck an International Review Panel ("Panel") to review evidence related to outcomes of Discovery Grants and its administration and to discuss key evaluation issues, with special attention to the effects of the recent changes.

The Panel met on July 11-12, 2013, and on September 8-9, 2013, both in Toronto, Ontario. The composition of the Panel is found in Appendix A.

1.2 Revised Peer Review System

Responding to the 2007 review, the two changes described below were intended to reduce "inertia"¹ and to better foster research excellence – a combination of research productivity and impact within the scientific community. The objective of these changes is to create an environment of healthy competition that ensures Discovery Grant funding supports a diversity of best ideas.

First, following the 2007 review, the process of adjudicating proposals and allocating awards was significantly revised from a one-step process to one that involves two steps: 1) evaluation of merit of

¹ Under the previous system, the value of a researcher's most recent Discovery Grant was usually within a small percentage of the previous one. Although there were variations by discipline, generally the value of a Discovery Grant did not increase significantly from one review period to the next, even for researchers with excellent track records. Conversely, researchers whose careers had taken a negative turn and/or who were submitting proposals with declining quality did not necessarily suffer immediately from significantly reduced funding.

the proposed research; and 2) assignment of a funding level. In the first step, Evaluation Groups no longer make direct funding recommendations for individual applications. And the history of past funding to an applicant is no longer a reference point used by the Evaluation Group to directly recommend increases or decreases in financial support. Therefore the assessment of Discovery Grant applications now separates merit review from the funding recommendation.

In the first step, Evaluation Groups assess all applications based on the three merit criteria (excellence of the researcher; merit of the proposal; and contributions to the training of highly qualified personnel) using a six-point scale. The six ratings used by the Groups are: Exceptional, Outstanding, Very Strong, Strong, Moderate, and Insufficient. These ratings lead to the grouping of applications into categories ("Bins") of comparable overall merit. Each application also receives a Cost of Research rating that reflects whether the costs of the proposed work (i.e., the "relative Cost of Research") are normal for the field of research or higher/lower than the norm.

In the second step, the Executive Committee of the Evaluation Group assigns a funding level to each merit bin, making adjustments at the bin level for the relative Cost of Research, as needed. All applications within a given Bin receive the same funding. Currently, NSERC attempts to fund all established researchers from Bin A (the Bin with the highest level of funding intended to fund top researchers at a level that is competitive internationally²) through Bin J (awards reflecting the minimum amount required to conduct quality research in that field). For Early Career Researchers (ECRs)³ the merit level to qualify for funding may be lower (e.g., Bin K or L) because there is only a very short track record on which to evaluate the quality of research performance.

A second significant change to the adjudication process was that a conference model was introduced to ensure the comprehensive assessment of Discovery Grant applications that cross boundaries between disciplines. In order to implement the conference model, the 28 Grant Selection Committees that previously provided reviews in focused fields of research were re-organized into 12 Evaluation Groups (EGs). Each Discovery Grant application is now reviewed by a lead EG; when necessary, members from other EGs join the lead EG to participate in the review and provide relevant expertise.

1.3 Charge to the International Review Panel

The Panel's mandate was to respond to the evaluation questions listed below. These questions were developed in consultation with the Research Grants and Scholarships Directorate senior management and NSERC's Committee on Grants and Scholarships; they address the core issues in evaluations according to the guidelines of the Treasury Board of Canada.⁴

Relevance:

The extent to which Discovery Grants continue to address a demonstrable need and are responsive to the needs of Canada and Canadian researchers.

² Note that the Discovery Grant alone is unlikely to be sufficient – top-tier researchers obtain significant additional funding from other Canadian and international sources.

³ NSERC guidelines define Early Career Researchers (ECRs) as researchers who are within two years of their first eligible academic appointment but without prior independent research experience.

⁴ Treasury Board of Canada Secretariat. 2009. *Directive on the Evaluation Function*. Available at: <http://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=15681§ion=text#appA>

1. To what extent is there a continued need to fund ongoing programs of research, including basic research, in the natural sciences and engineering?
 - 1.1. What is the role of Discovery Grants in providing a foundation that other funding programs build upon (e.g., NSERC Research Partnerships Programs and Scholarships and Fellowships Programs, Canada Foundation for Innovation funding)?
 - 1.2. To what extent do Discovery Grants facilitate the leveraging of funds from other sources?
 - 1.3. What role do Discovery Grants play in funding high-risk, novel or potentially transformative concepts and lines of inquiry?
2. Is there a necessary role for the federal government in providing Discovery Grants?
 - 2.1. What are the funding strategies of other key countries in support of basic research and how have these evolved since 2007?
 - 2.2. To what extent are features of the Discovery Grants approach and model becoming more evident within the strategies of other key countries?
3. Does the Discovery program continue to be aligned with NSERC and government-wide priorities in the area of science and technology? *(This evaluation question was not addressed by the Panel)*

Design and Delivery:

4. What impact have the changes to the peer review system had on the quality of the review process?
 - 4.1. Does the current EG structure and composition, introduced in 2009, remain appropriate?
 - 4.2. To what extent is the research cost factor applied as intended to address funding needs across various disciplines within one EG?
 - 4.3. To what extent is the budget information presented in applications relevant to the peer-review process?
 - 4.4. To what extent are the merit indicators and the information requested in applications appropriate?
5. To what extent is the current weighting of the three criteria appropriate relative to the objectives of Discovery Grants?

Effectiveness:

What impact have the changes to the peer review system had on NSERC's ability to meet Discovery Grants' three objectives, in terms of progress toward expected outcomes?

6. What impact have the changes to the peer review system had on promoting and maintaining a diversified base of high-quality research capability in the NSE in Canadian universities?
 - 6.1. Is an appropriate balance being maintained between the number of people supported and the size of grants?
7. What impact have the changes to the peer review system had on fostering research excellence?
8. What impact have the changes to the peer review system had on providing a stimulating environment for research training?
 - 8.1. What impact have the Discovery Accelerator Supplements had on grantees' ability to support additional HQP (i.e., students and postdoctoral fellows)?
 - 8.2. To what extent have the changes to the peer-review system raised the profile of the importance of training students?

9. How does the performance in research funded by Discovery Grants compare with that of funding systems in other key countries?

Efficiency and Economy:

Resource utilization in relation to the production of outputs and progress toward expected outcomes.

10. Are the most effective and efficient means being used to deliver Discovery Grants?
11. What efficiencies, if any, have resulted from the changes to the peer review system of Discovery Grants?
- 11.1. Was the increase in the participation of international EG members justified in terms of cost efficiency vis-à-vis the benefits on the quality of the peer review system?

1.4 Data Available to the International Review Panel

Data from a wide variety of sources were available to the Panel, including:

- Survey of Discovery Grant applicants:
 - Researchers who received a Discovery Grant in 2009-2012 (n=3,921);
 - Researchers who applied for a Discovery Grant in 2009-2012 but were not successful (n=895);
 - Researchers who applied prior to 2009 and whose awards were still active (n=1,269).

The response rate for the survey of applicants was 45.9% with the margin of error being $\pm 1.1\%$.

- Survey of the EG members who participated in application reviews since 2009 (n=395). The response rate for the survey of EG members was 47.8% with the margin of error being $\pm 3.6\%$.
- Interviews with the current and former EG Chairs and Section Chairs (n = 27).
- Administrative data review:
 - File review of all Discovery Grant applications submitted in 2010 (competition year 2011);
 - Review of administrative costs;
 - Review of the Statements of Account (Form 300).
- Consultations with scientific societies and university administrators.
- Document review.
- International comparison study.
- Bibliometric / citation analysis related to Canada's performance in NSE disciplines.
- Presentations to the panel by three guest researchers (see Appendix A).

Additional details regarding the various lines of evidence presented to the Panel may be found in Appendix B. Overall, the Panel believed the methodology is strong in providing the basis for reaching conclusions for all issues and questions using multiple lines of evidence. A description of limitations associated with these methods, as well as the strategies used to mitigate these limitations is found in Appendix C.

2. Findings on Relevance

2.1 Importance of Discovery Grants

Evidence: The evidence on this topic comes from every data source referenced earlier, including opinions of the research community, EG members and the international community, as well as analysis of NSERC performance data and bibliometric data.

Bibliometric measures show that Canada's share of world production of NSE publications has remained relatively stable at about 4% from 2001 to 2012, although it has declined from a high of about 4.4% in 2006. Canada's publication ranking has declined from seventh in 2006 to 10th in 2012, mainly because of increased production in countries with emerging scientific strengths (see Table 1).

Table 1. Canada's share of world papers in NSE publications

Rank	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Rank
1	US	US	US	US	US	US	US	US	US	US	US	US	1
2	Japan	Japan	Japan	China	China	China	China	China	China	China	China	China	2
3	Germany	Germany	China	Japan	Japan	Japan	Japan	Japan	Germany	Germany	Germany	Germany	3
4	UK	China	Germany	Germany	Germany	Germany	Germany	Germany	Japan	Japan	Japan	UK	4
5	China	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	Japan	5
6	France	France	France	France	France	France	France	France	France	France	France	France	6
7	Russia	Russia	Italy	Italy	Canada	Canada	Italy	India	India	India	India	India	7
8	Italy	Italy	Canada	Canada	Italy	Italy	Canada	Canada	Italy	Canada	Spain	Spain	8
9	Canada	Canada	Russia	Russia	Russia	Spain	India	Italy	Canada	Italy	Canada	S. Korea	9
10	Spain	Spain	Spain	Spain	Spain	India	Spain	Spain	Spain	Spain	Italy	Canada	10

Note: The rank of countries is computed for each year based on the number of papers in the NSE

Source: Computed by Science-Metrix from Web of Science (Thomson Reuters) and NSERC data

In terms of publication quality, however, Canada's Average Relative Citation factor (ARC⁵) in NSE has improved steadily over time, from 1.16 in 2001 to 1.25 in 2010, and to a rank of 16th worldwide (see Table 2).

⁵ A country's ARC is the average of the relative citation scores of its papers; i.e., of the number of citations received by its papers, normalized by the average number of citations received by world papers published the same year in the same specialty. An ARC value above 1.0 means that the publications of a given country are more highly cited than the world research average for that specialty; an index value below 1.0 means the reverse.

Table 2. Quality of Canada's scientific journal publications by year

Year	Average Relative Impact Factor (ARIF)	Average Relative Citation (ARC)	% in the top 5 percent of world's most cited papers
2001	1.12	1.16	5.97
2002	1.11	1.16	6.24
2003	1.11	1.19	6.07
2004	1.11	1.20	6.06
2005	1.12	1.17	6.32
2006	1.13	1.20	6.60
2007	1.13	1.22	6.82
2008	1.14	1.23	6.73
2009	1.15	1.24	6.71
2010	1.15	1.25	6.88
2011	1.15	n.c	n.c
2012	1.14	n.c	n.c

Note: n.c. = not complete

Source: Computed by Science-Metrix from Web of Science (Thomson Reuters) and NSERC data

The Panel noted Canada's strong international reputation in NSE research: both bibliometric and expert opinion data show that Canada has strong scientific performance above the world average, and that its quality performance has been improving over time — more NSE papers produced, more papers per researcher, and higher impact factors in absolute terms (although not relative to some other countries). As Discovery Grants are Canada's main support mechanism for broad-based NSE research (58% of journal publications from 2003 to 2012 were supported, at least in part, by Discovery Grants), this implies that Discovery Grants support excellence very effectively. Further, in most NSE fields, Discovery Grants-supported journal publications have higher quality, as measured by ARC and Average Relative Impact Factor (ARIF⁶), than those not supported by Discovery Grants (see Table 3 below).

Table 3. Impact of Canadian papers supported with Discovery Grants (2003–2012)

Field	Papers			Average Relative Citation (ARC)			Average Relative Impact Factor (ARIF)		
	Supported		Not supported	Supported	Not supported	p-Value	Supported	Not supported	p-Value
Engineering	22,527	72.8%	8,433	1.15*	1.03	0.000	1.12*	1.05	0.000
Information and Communication Technology	15,014	69.6%	6,543	1.26*	1.22	0.002	1.15*	1.14	0.000
Chemistry	18,520	68.2%	8,644	1.26*	1.12	0.000	1.27*	1.15	0.000
Mathematics and Statistics	9,278	68.1%	4,346	1.13*	1.02	0.000	1.07	1.05	0.573
Enabling and Strategic Technology	16,451	63.9%	9,305	1.24*	1.09	0.000	1.12*	1.08	0.000
Physics and Astronomy	26,306	63.4%	15,174	1.35	1.41	0.095	1.15	1.16	0.115
Earth and Environmental Sciences	12,254	58.4%	8,729	1.21	1.22*	0.000	1.16*	1.12	0.000
Biology	15,033	56.0%	11,795	1.32*	1.09	0.000	1.26*	1.01	0.000
Built Environment and Design	1,520	51.7%	1,420	1.08*	0.89	0.000	1.01*	0.97	0.000
General Science and Technology	2,821	42.6%	3,808	1.27	1.39	0.065	1.27*	1.12	0.000
Agriculture, Fisheries and Forestry	9,436	40.3%	13,970	1.35*	1.24	0.000	1.26*	1.14	0.000
Biomedical Research	18,414	37.8%	30,268	1.03	1.19*	0.000	1.03	1.10*	0.000

Note: For significant differences ($p < 0.05$), the higher value is indicated in bold green with an asterisk (*).

Source: Computed by Science-Metrix from the Web of Science (Thomson Reuters) and NSERC data

⁶ ARIF is the average impact factor of the journals in which a country's publications were found. It is a more indirect measure of quality than ARC.

Training of HQP is a common goal worldwide and it continues to be a strong goal for NSERC and Discovery Grants. Discovery Grants are a significant source of support for students: NSERC data show that roughly 60% of Discovery Grants funding was directed towards support for students, postdoctoral fellows (PDFs) and research technicians in 2011 (rising from about 52% in 2002). In 2013, just under 10 HQP were supervised on average per funded researcher (6.9 Canadian HQP and 2.8 international HQP). This is notably larger than the numbers of HQP supervised per unfunded researchers, at about seven in total (5.5 for Canadian HQP and 1.6 international HQP). Funded researchers report having slightly more Master's students, and twice as many PhD students and PDFs, as unfunded investigators. Researchers funded at higher Bins are more likely to have higher numbers of PhD students, PDFs and Canadian research associates and technicians.

Discovery Grants are intended to support programs of research. These programs represent the ongoing research interests of researchers, and Discovery Grants provide researchers with the flexibility to conduct their research in response to results and unanticipated opportunities, encouraging creative and cutting-edge approaches, and interdisciplinary or international collaborations.

Based on the survey of Discovery Grant applicants, Discovery Grants are believed to encourage Canadian researchers to participate in collaborations with other Canadian and international researchers. Approximately nine in ten Discovery Grant holders surveyed indicated that an absence of a Discovery Grant would have had an adverse effect on their ability to collaborate in Canada and abroad. The Panel noted that international collaborations can address problems too large for individual agencies, or even single countries (e.g., in subatomic physics).

This collaboration is facilitated by the flexibility that comes with Discovery Grants. Researchers are free to work in the mode most appropriate for their research area. Recipients of Discovery Grants are not restricted to the specific activities described in the application, but may pursue new research interests, provided they are within NSERC's mandate.

Conclusions: The Panel concluded that Discovery Grants are the core of Canada's support and funding for foundational research in NSE disciplines. Further, Discovery Grants support excellence, serve Canada well and appear to be unique worldwide in their design in supporting programs of research rather than specific projects. The program is highly valued, it is believed by the Panel to be envied in other countries, and it is widely seen within the Canadian research community as a credential of excellence, as well as a significant source of funding for HQP training (which is the single largest expenditure of Discovery Grant funds).

2.2 Alignment with Government Priorities

NSERC programs contribute to making Canada a world leader in advancing, connecting and applying new knowledge in NSE. Discovery is the largest one of NSERC's three programs, as depicted in NSERC's Program Alignment Architecture (PAA).⁷ The Discovery program consists of two sub-programs: 1) Discovery Research (of which Discovery Grants are the primary funding opportunity)

⁷ The three programs in NSERC's PAA are People (Research Talent), Discovery (Advancement of Knowledge) and Innovation (Research Partnerships).

and 2) Research Equipment and Infrastructure. NSERC's Report on Plans and Priorities (2013–14) notes that NSERC sustains Canada's capacity to conduct world-class research in the broad areas of NSE by supporting scientific excellence and seeding the creativity that leads to future innovations, and by supporting Canadian researchers so they can be global leaders and key players in international research collaborations.⁸

The objectives of the Discovery program are directly relevant to the priorities set out in the Government of Canada's science and technology (S&T) strategy, *Mobilizing Science and Technology to Canada's Advantage*. As noted in the S&T strategy, "University research generates tremendous benefits that are not predictable at the outset. It is important for society and for Canada's private sector that universities continue to explore lines of enquiry that will seed longer-term social and economic opportunities. Public support for basic research is justified by the fact that the benefits to society are significant. Without government support, many discoveries that have generated important economic and social benefits would never have materialized."⁹

Discovery Grants are intended to foster research excellence and to promote and maintain a diversified base of high-quality research capability in the NSEs in Canadian universities. These objectives contribute to fostering the knowledge advantage outlined in Canada's S&T strategy; it ensures Canadian universities and colleges sustain their world-class research excellence.

Discovery Grants also aim to provide a stimulating environment for research training. This contributes to fostering the S&T strategy's people advantage, so that Canada has access to the highly skilled researchers and innovators it needs. The strategy concludes that "talented, skilled, creative people are the most critical element of a successful national economy." It emphasizes the importance of investing in the education and skills development of Canadians at all levels of higher education and throughout their lives.

Investment in knowledge and people remains one of the priorities of the government. This was emphasized in the 2013 Throne Speech, which states that the Government of Canada "will continue making targeted investments in science and innovation chains from laboratory to market in order to position Canada as a leader in the knowledge economy."¹⁰ The Economic Action Plan 2014 "*The Road to Balance: Creating Jobs and Opportunities*" recognizes that "the creation of knowledge, application of scientific discoveries and development of highly qualified people bring social and economic benefits to all Canadians."¹¹ The Action Plan proposed to provide support to NSERC for advanced research and scientific discoveries in the natural sciences and engineering.

2.3 Unique Design of Discovery Grants

Evidence: When compared globally, there are two unique elements of Discovery Grants: (1) they support five-year terms of "individual programs" of research, rather than specific projects; and

⁸ NSERC. *Report on Plans and Priorities 2013–14*. Available at: http://www.nserc-crsng.gc.ca/NSERC-CRSNG/Reports-Rapports/RPP-PPR/2013-2014/index_eng.asp

⁹ Government of Canada. 2007. *Mobilizing Science and Technology to Canada's Advantage*.

¹⁰ Speech from the Throne. October 16, 2013. Available at: <http://speech.gc.ca>

¹¹ The Road to Balance: Creating Jobs and Opportunities. 2014. Available at: <http://www.fin.gc.ca/pub/pdfs/budget2014-eng.pdf>.

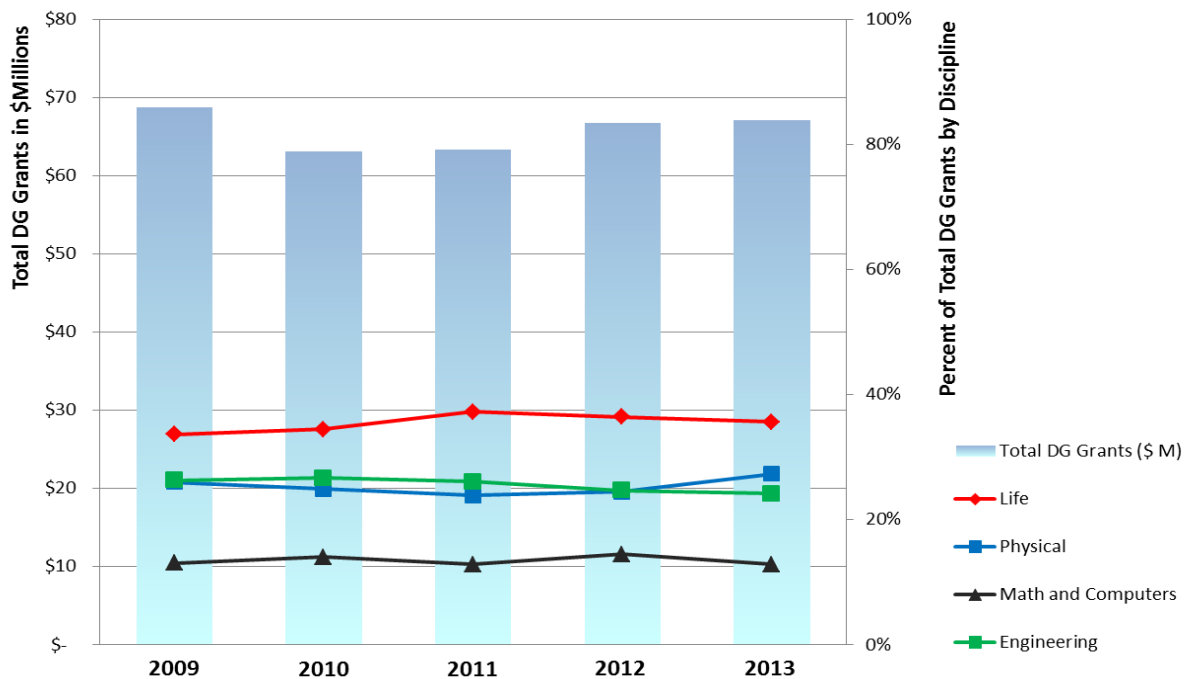
(2) Discovery Grants have relatively high success rates compared with other programs supporting broad-based research projects.

Discovery Grants support “individual programs” of research. (A small number of team Discovery Grants are also awarded, but most awards are to individual researchers for a five-year program of investigation.) By contrast, virtually all other broad-based research support in Canada and abroad is tied to specific projects. Research project funding tends to be shorter-term, with explicitly defined deliverables and time frames and, consequently, permits little flexibility for the grantee.

Researchers can apply for and hold only one Discovery Grant at a time, which supports a relatively high Discovery Grants success rate. (In other international programs supporting research, researchers are typically permitted to apply for and hold multiple grants at one time, thus effectively increasing their chance of having some grant funding, and lowering the success rates for a given cohort of applications.) This five-year programmatic support provides significant benefits in terms of each researcher’s flexibility to pursue promising research avenues as they emerge and provides opportunity to address higher-risk (higher reward) topics.

The data also show that Discovery Grants support a highly diversified base of research across many disciplines (see Figure 1) that has been fairly consistent over the past five years.

Figure 1. Discovery Grants by discipline



Source: NSERC Administrative Data

The Panel addressed the question of whether significantly reducing the success rate would meaningfully increase the size of the average Discovery Grant. This is an important question, given that the Discovery Grant is intended to be a “grant in aid”; for the majority of researchers, the Discovery Grant is smaller than the funding necessary to conduct a competitive research program. Simulations indicate that if successful Discovery Grants applications currently falling in the lowest 30% of merit bins were no longer funded, the size of the average Discovery Grant would increase by

only \$1,500 to \$7,000. This would, however, translate into a reduction of 3000 supported researchers (from roughly 10,000 to 7,000).

While the average increase in Discovery Grants would be limited (e.g., not even enabling the full support of one graduate student), the fact that the research programs of a substantial number of researchers would no longer be supported would have an extensive and multifaceted impact. Indeed, besides affecting NSE research at smaller institutions across the country, the pool of supervisors for a large number of HQP would be substantially reduced. With the limited increase in the average Discovery Grant for the remaining researchers, it would be difficult for supported researchers to compensate for that loss. Training of the next generation of Canadians would thus be reduced while the demand for a highly skilled workforce is continuously increasing. Furthermore, the Discovery Grants of researchers who are at an early stage of their careers, and who are still establishing their research programs, typically fall in the lower merit bins. This is simply a reflection of the fact that they are still lacking a track record of independent research, not that their research prospects are limited. By not supporting the lower fraction of currently funded merit bins, the review process would not enable supporting the upcoming generation of researchers.

Conclusions: While a few panel members had initially raised the question of whether the modifications to the peer review system had gone far enough in focusing on excellence, the Panel concluded that, within the Canadian context, the Discovery Grants provide a good balance between supporting excellence and supporting a broad base of research. (The strong scientific performance of Canada in NSE shows that the relatively high success rates do not diminish the quality of Canadian science, which remains very high.) Discovery Grants also provide a healthy environment for the training of HQP such as graduate students and PDFs.

2.4 Global Context for Discovery Research

Evidence: Other countries' granting programs are experiencing an increase in the number of applications and declining success rates. This is especially true in the wake of the global financial crisis, which has had major impact on other countries' priorities, resulting in considerable experimentation in program design across a broad suite of support for R&D, including

- more attention to global networks and collaborations, leveraging resources from these sources;
- more national linkages and collaborations;
- more attention to achieving identifiable results and impacts, and demonstrating a significant return on investment (ROI); e.g.,
 - increasing strategic links to, and promotion of, key technologies (e.g., nanotechnology, synthetic biology, genomics);
 - setting national R&D targets;
 - developing new research governance structures;
 - using more methods to demonstrate ROI (e.g., metrics, success stories, "nuggets," vignettes, social media); and
 - increasing attention to metrics and measurement of outcomes and impacts.
- more mechanisms to attract foreign talent; and

- increased use of prizes (e.g., the Longitude Prize in the UK, the XPRIZE Foundation in the US).

In response, there have been significant increases in funding for broad-based research in some other countries, and there are several important new players on the international research scene, such as China, Brazil and India. Although Canada has substantially increased support for science (e.g., Canada's higher education sector expenditure on R&D (HERD) has grown more than fourfold since 1980 at 2005 constant prices), similar trends are also observed in other countries, such as Australia, US, Italy, and Netherlands. Canada has only managed to maintain its position in this competitive world, but not improve it. As a result, Canada risks lagging behind in both HERD and support for discovery research. The Panel noted that, while academic employment in Canada is highly attractive to international researchers because of the high international regard for Discovery Grants, good university salary structures and other programs such as Canada Research Chairs, Canada may be slipping somewhat in the global research environment.

Conclusions: While the evidence shows that Canada has been performing well in terms of quality of research, the Panel believes Canada is stagnating in terms of growth in investment in discovery research in comparison with other countries,¹² and this should be a cause for concern. The Panel further noted that increased emphasis on ROI may threaten the sustainability of support from government for Discovery Grants. It is essential that the uncertainty associated with the timelines from broad-based research through to practical application is fully understood by government officials and policy-makers.

2.5 Grant in Aid and Leveraging

Evidence: NSERC considers Discovery Grants to be a “grant in aid” of research. The average Discovery Grant is currently about \$35,000, ranging from a low disciplinary average of about \$19,000 in mathematics and statistics to a high disciplinary average of about \$55,000 in chemistry. The amounts are not meant to support the full costs of a research program in these fields; instead, they are intended to facilitate access to funding from other programs, which is often referred to as their “leveraging” effect. Successful applicants use it as a springboard to apply for and obtain research funding from a multitude of other sources. These include NSERC's other funding programs (such as those supporting research in strategic areas and industry-driven research), programs of the other two granting agencies,¹³ other national programs such as the Canada Foundation for Innovation and Genome Canada, and/or programs of other organizations such as the National Research Council Canada, provincial S&T support programs, contracts with industry and (where eligible) international programs.

¹² For example, Canada's research intensity, as measured by the ratio of gross expenditures on R&D (GERD) to gross domestic product (GDP), has been trending downwards over time, mainly because of low business expenditures on R&D (BERD), whereas GERD/GDP in many other countries is ramping up.

¹³ The Canadian Institutes of Health Research (CIHR) and the Social Sciences and Humanities Research Council (SSHRC). Some NSE researchers are in interdisciplinary fields that make them eligible for NSERC and CIHR and/or SSHRC funding.

Discovery Grants appear to assist researchers to obtain other research awards. First, data from the survey conducted in 2013 show that funded researchers had total research support of about \$130,000 from all sources¹⁴ on average. Overall, the Discovery Grants funding alone represents only about a quarter of the total research funding obtained by funded researchers on average. In addition, scientists with Discovery Grants have substantially more funding from non-Discovery Grant sources than those without Discovery Grants. Discovery Grant holders are also more likely to be successful when applying to other NSERC programs, and researchers in the top Discovery Grant Bins obtain more non-Discovery Grant funding than investigators in the lower Bins. Nine of ten Discovery Grant holders surveyed stated that a lack of a Discovery Grant would have had an adverse effect on their ability to leverage funding from other sources.

Further, data from the community on the required grant size compared with the actual award amount show that Discovery Grants must be supplemented by funds from other sources in order to conduct a competitive research program. Respondents from the survey of researchers estimated that a “sufficient” average Discovery Grant amount is roughly \$41,000 for funded early career researchers (compared with the actual \$27,000); \$56,000 for funded established returning researchers (compared with the actual \$34,000); and \$97,000 for top-tier researchers (Bins A through C, compared with the actual \$88,000). Both funded and unfunded researchers perceived this gap similarly. The actual average Discovery Grant amount, in the Panel’s experience, was only just sufficient to support one PhD student, although this varies considerably by field, institution and remuneration source for students and other HQP.¹⁵

Conclusions: It was clear to the Panel that holding a Discovery Grant was associated with holding other grants. However, the extent to which Discovery Grants allow researchers to “leverage” other funding was considered unclear by the Panel. For example, Discovery Grant award-holders — and especially the top-tier researchers — might simply represent the higher-calibre researchers, who are better able to obtain all forms of research support, Discovery Grants and non-Discovery Grants alike.

While there is no compelling evidence to demonstrate a causal link between a Discovery Grant and funding from other sources, the Panel noted that the community perception of Discovery Grant awards in this context is clear: there is a very strong belief in the community that the ability to obtain a Discovery Grant is a keystone criterion for having achieved an acceptable level of research excellence, and leveraging is also believed to be a highly important feature of Discovery Grants.

The Panel recommended moving away from “leveraging” terminology, as there are no expectations of co-funding or matching funding for Discovery Grant award-holders, which the term “leveraging” usually implies. It was suggested that terminology such as a “multiplier effect” or a “halo effect” may be more accurate than “leveraging.”

¹⁴ Excluding researchers’ own salary and funding for equipment and operating costs of shared facilities.

¹⁵ In Alberta, for example, the universities may pay HQP salaries, so that research grants need not be used for this purpose.

2.6 Nature of Research Supported

Evidence: The Panel pointed out that Discovery Grant-supported research is by no means exclusively “curiosity-driven” in nature, and the meaning of “curiosity-driven” varies by discipline. The Panel was concerned by the perception of the Canadian academic community (based on submissions from learned societies and survey data) that Discovery Grants were moving more towards the support of applied work, at the expense of fundamental research. While survey of applicants conducted for the evaluation in 2007 revealed that researchers rated Discovery Grants significantly higher in terms of encouraging fundamental research versus applied research in their field, in 2013 this difference reduced considerably, and, in the researchers’ perception, Discovery Grants currently encourage applied research almost as much as they encourage fundamental research. NSERC itself does not hold this opinion, nor do its funding guidelines imply any such shift. Further, the changes brought about by the new peer review system were thought unlikely to create this perception, and the Panel wondered whether opinions might be coloured by a perception of increasing federal government emphasis on generating concrete socioeconomic benefits.

Having said this, the Panel acknowledged the remark of one of the guest presenters: “The Discovery Grant was my venture capital.” That is, the Discovery Grant allowed this investigator to pursue research that was very fundamental in nature at first (and therefore not at all amenable to conventional venture capital), but that later became of interest internationally and applied both in practice and for policy purposes. Discovery Grants provided support for the fundamental discoveries that drove the later successful applications while simultaneously opening up new fundamental discoveries that continue to be explored by this researcher. Freedom to pursue a program of research that can move strategically back and forth between discovery and application of discovery is seen by the Panel as a strength of the Discovery Grants.

Regarding the potential practical relevance of Discovery Grant research, the Panel was struck by bibliometric data showing that only 2%–3% and 8%–10% of Discovery Grant-supported researchers co-publish with industry and government, respectively, and this co-publication rate decreased (albeit slightly) as Bin quality level increased. This surprising result led the Panel to believe that the industry-linked research is not normally published in peer-reviewed journals (being more applied in nature). It was also suggested that a substitution of the source of funding could occur when Discovery Grant funding is not sufficient, perhaps through increased partnerships with the industry and governments.

2.7 Discovery Grant Support for High-Risk Research

Definition of “high risk”: The Panel first noted that “high risk” is very difficult to define (and assess) and is often self-defined. Further, the Panel noted that Discovery Grants support different types of risk. For example, one type of high-risk research is often called “blue sky,” being highly innovative and potentially transformative. Other investigations can be risky for the investigator’s career if they fail. The Panel noted that partnership programs often support certain kinds of high-risk investigation; for example, projects intended to develop commercial ventures can easily fail, whereas even null results in foundational research can be very valuable. It was further noted that the length of the term of the Discovery Grant (typically five years) could help lower the barriers to addressing higher-risk topics.

Bibliometric analysis is not necessarily helpful in defining risky research. In fact, programs supporting high-risk research can have poorer bibliometric results because they may fail and not yield results, which would then not be published.

Evidence: In this context, a highly relevant feature of Discovery Grants is that they support a program of research for individual investigators, usually for five years, rather than specific projects. Such program support for individuals has the benefit of allowing a more unrestricted pursuit of research topics over the course of the grant as interesting findings emerge, and of permitting relatively unfettered pursuit of long-term research interests (especially on foundational questions). Thus, Discovery Grant holders can afford to pursue a mix of relatively high-risk research avenues (including following unexpected findings very quickly) and more conservative topics over the term of the grant. Six in ten funded applicants characterize their research as involving novel and potentially transformative concepts and lines of inquiry “to a great extent,” and seven in ten agree that the Discovery Grant encourages this kind of research. Overall, 87% of funded applicants characterize their research as being high-risk at least to some extent. Unfunded applicants are less likely to characterize their research as high-risk (77%). Discovery Grants can also be used to support higher-risk programs undertaken by PDFs or research associates, unlike the relatively lower-risk topics that are more appropriate for graduate students. By virtue of the unique program nature of the Discovery Grants, all of this is achieved without requiring separate funding or allocation mechanisms.

The evidence from the surveys regarding the extent to which Discovery Grants support high-risk research is mixed: similar proportions of applicants (about one-third) believe that the program encourages high-risk research, as those who think that it does not. Those who have been unsuccessful in securing Discovery Grants funding are more likely to believe that Discovery Grants do not encourage high-risk research (58%). The Panel discussed that top-tier investigators may have more ability to perform risky research simply because they are more productive, highly organized and highly successful at obtaining research support. They essentially have a “safety net” that allows them to pursue several lines of investigation simultaneously and to switch topics as findings are obtained.

The Discovery Accelerator Supplements (DAS), which was launched before the implementation of the changes to the peer review system (noted in Section 1.2), was originally intended to quickly ramp up the funding to investigators who could capitalize on important research opportunities that require rapid response to be competitive. The original intent of DAS awards had been appropriate because of the inertia found under the peer review system before 2008–09. Although it is still somewhat early to fully assess the originally intended impact of the DAS, bibliometric evidence indicated limited impact of the DAS awards on research quality and productivity to date.

Over time, the DAS has changed focus and is now intended to support highly original and innovative research, especially high-risk, novel or potentially transformative ideas that are likely to contribute to ground-breaking advances in the area.¹⁶ Further, as it was initially intended, DAS no longer seems necessary given the new Discovery Grant peer review system is working properly to reduce inertia. Competition results indicate that EGs have shifted towards recommending DAS awards only to top Bin applicants, which is not the intent, but may indicate that EGs feel that top-tier investigators are

¹⁶ The EGs make recommendations for DAS awards during the Discovery Grant application review process. No separate DAS application is required; the supplement is delivered in conjunction with the Discovery Grants for reasons of administrative simplicity.

better able to perform risky research. Data from the survey of researchers suggest that DAS has met the most recent goals, as the majority of DAS recipients strongly believe that the award enabled them to explore more novel and potentially transformative concepts and lines of inquiry and to conduct more high-risk research.

Conclusions: The Panel did not reach a firm conclusion regarding the extent to which Discovery Grants support risky research, mainly due to the difficulty of defining exactly what high-risk research is: the nature of perceived risk varies significantly depending on who is reviewing the research, at what stage and for what purpose. The Panel did note, however, that research funding programs that follow the opposite route – i.e., those that provide project grants with higher average funding but with significantly lower success rates – tended to foster low-risk research if there is no separate pool of funds for high-risk topics. By implication, the Discovery Grants’ relatively higher success rates, five-year terms and flexibility provide opportunity for high-risk topics to be investigated.

Conflicting data from the community consultations suggested that the shift in DAS goals has not been clearly communicated and the selection process is not transparent. The Panel noted that it was too early and there was insufficient evidence to comment on the success of DAS in its current format in supporting high-risk research, and questioned whether indeed it does. Further, the funding provided (\$120,000 over three years per award) was considered rather low to support truly innovative research in some fields. Given the challenges associated with defining and assessing “high risk,” the Panel recommended refining the DAS away from the purpose of supporting high-risk research. It was noted that simply rolling this amount into the Discovery Grants would make a small (at best 5%) difference to the average Discovery Grant. A proposed alternative focus for DAS funds is discussed in a subsequent section.

3. Findings on Effectiveness

3.1 Impact of Changes to the Peer Review System on Fostering Excellence and Reducing Inertia

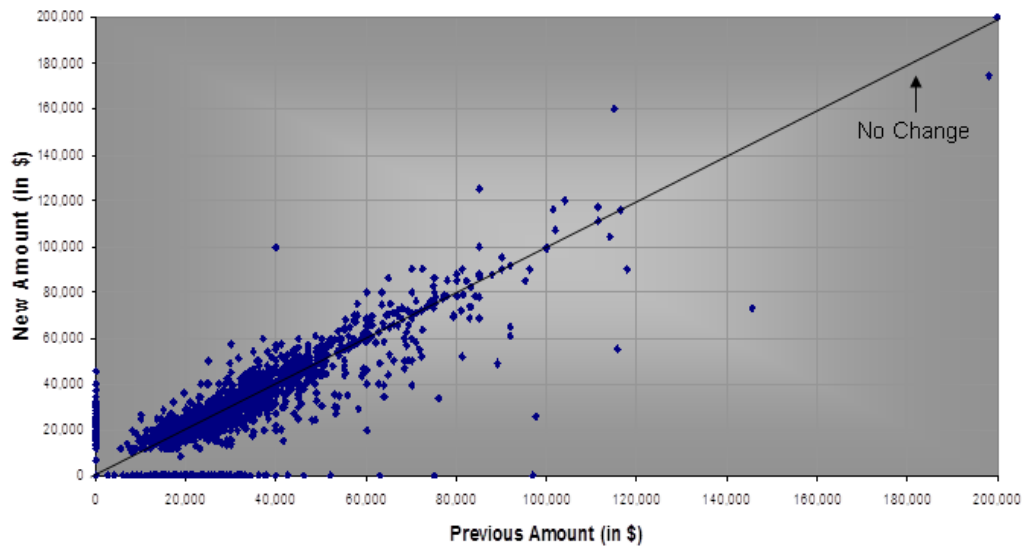
Evidence: NSERC administrative data show that Discovery Grant expenditures have increased by about \$71 million from 2004–05 to 2013–14 (not adjusted for inflation). The average grant size has increased slightly from about \$31,000 in 2008–09 to roughly \$35,000 in 2013–14. However, this increase has not been in real dollars, and the Panel was concerned over the erosion of the purchasing power of a Discovery Grant during this period. The number of Discovery Grants awarded annually has been decreasing slightly (from about 10,300 in 2008–09 to about 9,700 in 2013–14). In particular, the success rate for renewals (i.e., researchers previously holding a Discovery Grant) has declined significantly since the changes to the peer review system; from 88% of applicants in 2008, to 79% in 2009, 71% in 2010, 74% in 2011, 78% in 2012, and 76% in 2013. If this decline can largely be attributed to the new review system, it has enabled the support of the most meritorious research programs at a level that contributes to making them more competitive at the international level.

The number of Early Career Researchers awarded Discovery Grants has also declined recently, but this is as a result of a reduction in the number of applications (and likely tied to lower university hiring), rather than any decline in the success rates for Early Career Researchers.

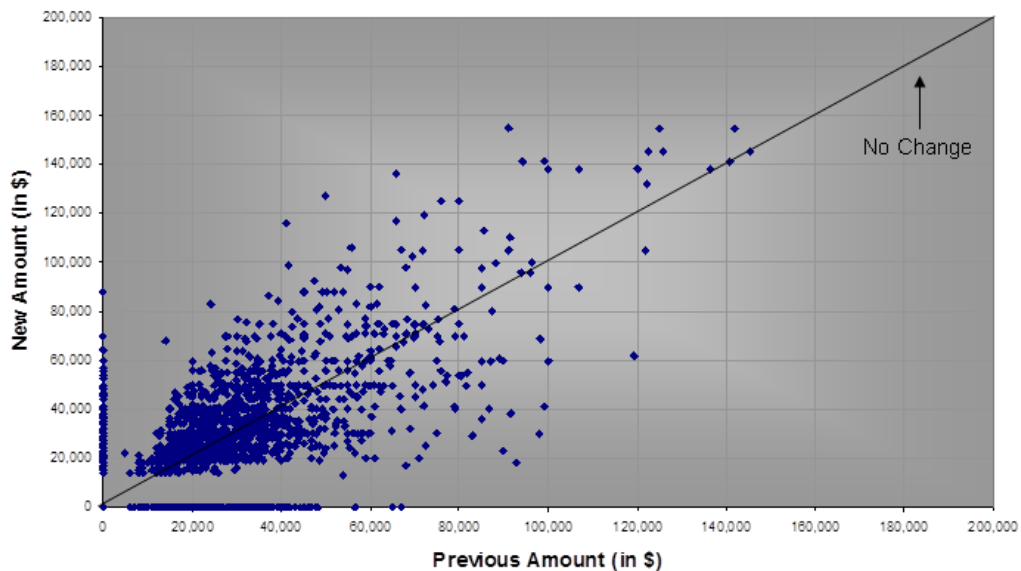
Regarding inertia, the awards data (see Figure 2) clearly show considerably greater scatter in the change in amount of the most recent Discovery Grant award compared with the previous award — that is, the size of renewal awards is far less closely tied to previous grant amount than before the review system changed (as was the intention). Further, there is considerable anecdotal evidence that established researchers have realized that, to succeed under the new system, they cannot just “touch up” previous research proposals but need to present a compelling application addressing all three selection criteria.

Figure 2. Change in grant level for Discovery Grant renewal applications

Change in Grant Level for Renewal Applicants – Before the Changes to the Peer Review System (2008 competition)



Change in Grant Level for Renewal Applicants – After the Changes to the Peer Review System (2009 competition)



Source: NSERC Administrative Data

Regarding support for excellence, the bibliometric analyses show a strong association between higher Bin levels and higher productivity: the average number of papers per investigator increases by 45% to 55% between the first three bins and the second three, and so on. As well, the average number of publications per researcher is significantly different between funded researchers in Bins J–P and unfunded researchers in Bins K–P (see Table 4). Similar differences in scientific quality of publications were found in the analysis by ARIF, with an increase in ARIF of roughly 3%–5% between each group of three Bins and the next (see Table 5). The Panel commented that these analyses would likely be even more striking if it were possible to identify and quantify truly transformative papers.

Table 4. Association between funded bin level and subsequent individual productivity

Group	Bin level CY 2009 + CY2010	No. of researchers	Average papers/researcher 2011-2012	Difference	Median	Mean Rank Sum	p-value
1	K-P (not funded)	1,660	2.76	➤ +56.8%	2	1,859	➤ 0.000
2	J & K-P (funded)	1,179	4.32	➤ +44.2%	3	2,499	➤ 0.000
3	G-I	1,701	6.24	➤ +52.9%	4	2,977	➤ 0.000
4	D-F	593	9.53	➤ +57.6%	7	3,654	➤ 0.001
5	A-C	88	15.02		12	4,195	

Source: Computed by Science-Metrix using Web of Science (Thomson Reuters) and NSERC data

Table 5. Association between funded bin level and subsequent scientific quality

Group	Bin level CY 2009 + CY2010	No. of papers	Average Relative Impact Factor (ARIF) 2011-2012	Difference	Median	Mean Rank Sum	p-value
1	K-P (not funded)	4,329	1.12	➤ +3.2%	1.00	12,276	➤ 0.001
2	J & K-P (funded)	4,848	1.16	➤ +1.3%	1.03	12,773	➤ 0.406
3	G-I	9,894	1.17	➤ +4.5%	1.03	12,876	➤ 0.035
4	D-F	5,407	1.23	➤ +4.9%	1.05	13,147	➤ 0.000
5	A-C	1,273	1.29		1.14	14,118	

Source: Computed by Science-Metrix using Web of Science (Thomson Reuters) and NSERC data

Bibliometric data on researchers who did or did not receive DAS support, and on productivity before and after DAS support, showed relatively small and somewhat inconsistent effects on productivity and quality as measured by ARIF. However, these data were difficult to interpret, since DAS has recently changed its emphasis from being an “accelerator” for researchers showing high potential to being a support mechanism for “high-risk” research, and some of the DAS researchers in the analytic cohort were supported under the previous system.

Although the comments from the researcher community were roughly equally divided about whether the changes to the peer review system are positive or negative, this was almost completely explained simply by whether a given researcher had received more or less funding in the most recent competitions.

Summary: The Panel commented that the actions stemming from the last international review of Discovery Grants in 2007 demonstrated a real desire for change on NSERC’s part, and that the data show the intended impacts have been achieved — more productivity and impact (excellence) and significantly less inertia, coupled with slightly higher average funding per successful applicant. Further, the new Bin system was demonstrated to be a robust method for ranking applications by quality. Overall, the Panel believed the message from the 2009 changes about increased attention to merit has now been received by the community.

The Panel had been somewhat divided initially on the topic of whether the focus on excellence had gone far enough, but the balance of opinion is that, in the Canadian context, NSERC had done a good job of striking a balance between supporting a broad base of research at diverse universities, and supporting productivity and impact. It was noted that it is difficult to assess the question of balance between grant size and numbers of researchers supported, simply because the nature of a grant in aid is that most investigators have access to significant additional funding. The Discovery Grant, defined in this way, cannot be expected to cover the entire funding needs of each researcher, but the Discovery Grant is clearly associated with success in gaining other sources of funding.

3.2 Impact of Changes to the Peer Review System on the Quality of the Review Process

Evidence: The responses of the community consultations strongly suggested that opinions on whether the new system met its goals (increased focus on excellence and reduced inertia) depended on the respondent's success in the new system: those receiving higher Discovery Grant awards under the new system generally believed that the new evaluation group structure enabled NSERC to conduct a thorough review of their most recent proposal, whereas those researchers whose funding had decreased or who had not been successful usually believed the opposite.

The Panel noted that a large majority of EG respondents, by contrast, were positive about the changes (and even more so than successful applicants), believing that the new system better allowed appropriate funding for meritorious applicants regardless of career stage and better enabled EGs to increase grant amounts in renewal applications.

Conclusions: The Panel recognized that the changes were not accepted universally but found that the split opinions of researchers were as expected, given the natural self-interest of the respondents. Significant weight was placed on the views of EG members, who had more of an overview of the entire process and (some of whom) had seen both systems in practice. Further, the data on the increased variability of most recent grant size versus size of previous grant (and especially the higher number of unfunded researchers among applicants under the new system) and the bibliometric results strongly suggested that the goal of fostering excellence had been met.

3.3 Appropriateness of Evaluation Group Structure

Evidence: EG members who had participated in the new review process noted that they were satisfied with the appropriateness of the research topics reviewed within their EG, that mainstream applications were thoroughly reviewed, and that joint reviews involving members of other EGs were effective in assessing multidisciplinary and interdisciplinary proposals. Evidence from EG members suggested that the conference model allows access to more expertise when needed and permits a more thorough review of applications in emerging areas and interdisciplinary/multidisciplinary applications, particularly for mainstream applications. The process was said to work well and resulted in a more fair and equitable process that successfully fostered excellence. Only 6% of EG members surveyed indicated that the current EG structure and the conference model did not allow a thorough assessment of interdisciplinary and multidisciplinary applications.

The Panel found no reason to believe the new conference model was inappropriate. The Panel reflected on the views of EG members and cited the relatively low numbers of interdisciplinary or joint reviews in recent competitions, which demonstrated that the broad expertise within individual EGs was sufficient. For example, during the period 2010-2013, applications in Physical Sciences were reviewed by a total of 14,571 reviewers, of whom only 391 reviewers came from the Evaluation Groups belonging to other disciplines. For other disciplines, this ratio is even lower. These data suggest that expanding the fields within each EG and employing a conference model has been successful. The Panel also endorsed the fact that joint reviews could be suggested by either the EGs or the applicants themselves.¹⁷

Conclusions: The Panel believed that the conference model works well and is certainly better than the previous system for multidisciplinary proposals. Although handling multidisciplinary proposals posed some challenge for evaluation groups, the EG reviewers overall like the model and understand it.

3.4 Ability of Discovery Grants to Support Early-Stage Researchers

Evidence: The Panel was slightly concerned about the lower success rates¹⁸ for researchers at an early stage of their career (either first application or first renewal), as this reflects their challenges in documenting a high-quality career, preparing a high-quality proposal and building a sufficient cadre of HQP. In this section, the term “early-stage researchers” is used rather than Early Career Researchers, as the definition of ECRs is restricted to those within two years of their first eligible academic appointment but without prior independent research experience.

The Panel also discussed the timing of obtaining a renewal Discovery Grant in conjunction with tenure review. Many Canadian universities review tenure within four or five years of hiring, at which point early-stage researchers have not yet had much chance to establish laboratories, build a research team or demonstrate their quality, and they cannot yet apply for a renewal of their Discovery Grant (which might increase on renewal). On the other hand, the Panel noted that university tenure committees might need to make a decision for tenure taking into account a first Discovery Grant, without knowing whether it would be renewed. Thus, an unintended impact of the program is that there is some mismatch between the Discovery Grants term and the career path of these early career investigators. This issue is likely to become increasingly prominent as baby boom-age researchers retire and need to be replaced.

Conclusions: The Panel considered several alternatives to address this issue, but recommended one that is relatively simple within the current Discovery Grant structure: allowing early-stage researchers,¹⁹ at their discretion, to ask for an early first renewal if they prefer not to wait until the end of their first five-year Discovery Grants term. This could help researchers at the beginning of their careers to increase the amount of their grant in order to continue to build their team, develop their lab,

¹⁷ Staff can also trigger consideration of joint reviews based on a review of Research Topics in the application (i.e. the use of Research Topics associated with different EGs).

¹⁸ Recent success rates for ECRs were 60% compared with 76% for established researchers.

¹⁹ The Panel recommended limiting this option to researchers within 10 years of their PhD. It should be noted that this is somewhat different from how NSERC guidelines currently defines ECRs, which are researchers who are within two years of their first eligible academic appointment, without prior independent research experience.

and demonstrate quality. Researchers who successfully obtain an early renewal would enter the tenure process with more track-record for review (although with the obvious risk of not obtaining the renewal). This would not require any changes to current success rates or the Bin system. The early renewal would be structured so that

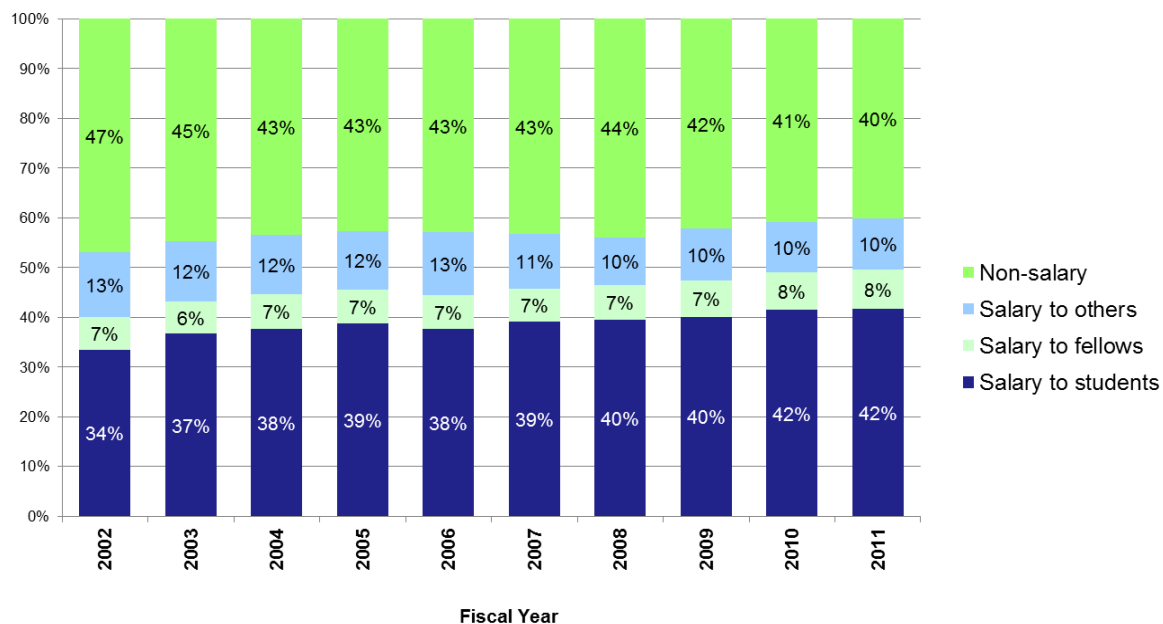
- early first-renewal applicants would be competing with all other Discovery Grant applicants applying in same year;
- the decision of the EG would be final for all applicants in these competitions, whether they were “normal” renewals after five years, or an early first renewal after three or four years; and
- first renewals would be monitored and their outcomes reported separately from subsequent renewal applicants.

The Panel recommended targeted funds for early-stage researchers and first-renewal applicants showing the greatest potential at a critical point in their career. Any additional funding required could come from the modifications to DAS discussed above.

3.5 Impact of Changes to the Peer Review System on Research Training

Evidence: The fact that Discovery Grants support research programs rather than research projects means they are more amenable to providing reliable, ongoing support for laboratories and HQP. By contrast, when research is supported through project grants, there are often difficulties in providing bridge funding to these laboratories and HQP when shorter-term project grants terminate. (Panel members mentioned the struggles in these areas experienced by colleagues in countries such as the US when project funding terminated.)

Figure 3. Share of Discovery Grant expenditures aimed at HQP costs



Source: Statements of account submitted by Discovery Grant holders

Investigators funded under the new peer review system believe, on average, that the changes have not affected HQP training, while unsuccessful applicants believe the changes have had a negative impact. The Panel concluded that the latter finding makes sense, since Discovery Grants are a significant source of training support. The Panel believed that the only two negative impacts would be (1) less assurance of funding continuity under the new system, potentially making the support of large laboratories and numbers of HQP more problematic; and (2) difficulties in ramping down labs and teams when an established investigator receives a “null award” (i.e., the application is unsuccessful).

Conclusions: There was no apparent major impact of changes to the peer review system on training of HQP. However, there is potential for training disruption when an established researcher obtains a significantly decreased renewal, especially a “null award.” When new awards are significantly lower than the previous one, the Panel noted that NSERC could consider ramping the funding down gradually to allow support of research teams during the transition period.

3.6 Impact of the Discovery Accelerator Supplements on Research Training

Evidence: Over 80% of DAS recipients reported the award allowed them to hire additional research staff “to a great extent.” DAS recipients have higher number of PhDs than other funded researchers who received no DAS award (about 4.11 versus 2.65, respectively), and also more PDFs than non-DAS funded investigators (about 1.34 versus 0.78, respectively). There was no significant impact of the DAS award on numbers of undergraduate or graduate students, research associates or technicians supervised by Discovery Grant holders.

Table 6. Average number of HQP who currently make up funded applicants’ research team

	Canadian HQP			International HQP		
	DAS recipients	Funded applicants – Non-DAS	Overall	DAS recipients	Funded applicants – Non-DAS	Overall
Undergraduate students	2.59	2.40	2.42	0.34	0.36	0.36
Masters students	1.80	1.72	1.72	0.87	0.77	0.78
PhD students	2.39*	1.54*	1.59	1.72*	1.11*	1.15
Postdoctoral students	0.67*	0.41*	0.43	0.67*	0.37*	0.39
Research Associates	0.42	0.34	0.35	0.06	0.09	0.09
Technicians	0.42	0.37	0.37	0.03	0.03	0.03
Total	8.29	6.78	6.88	3.69	2.73	2.80

Source: Survey of Discovery Grant applicants, 2013

Note: Significantly different results (p-value < 0.05) are indicated in bold green and by an asterisk (*).

Conclusions: The Panel found that DAS has a small but significant impact on the number of PhDs and PDFs supervised by Discovery Grant award-holders.

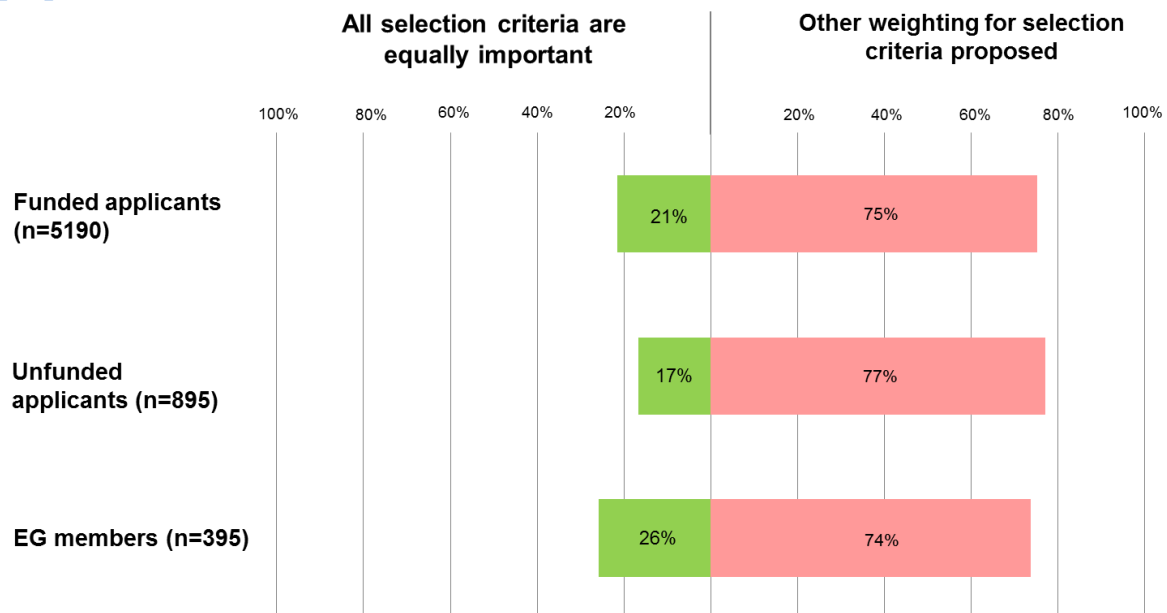
3.7 Appropriateness of the Merit Indicators Used to Review Applications

Evidence: The current evaluation criteria on which EGs rate applications are excellence of the researcher, merit of the proposal and contribution to HQP training, with each criterion being equally weighted in the review process. NSERC provided information on exactly how the merit indicators that enable the assessment of the criteria are worded and how they are used by the EGs, as well as opinions of the research community on their appropriateness.

Among the three criteria, training of HQP appears to be less clear than the other two. This sentiment is shared by applicants and EG members alike. Only half of EG members agreed that the merit indicators allowed them to thoroughly assess applications against the training of HQP criterion “to a considerable extent.” EG chairs also experienced less comfort with the training of HQP criterion than with the other two criteria.

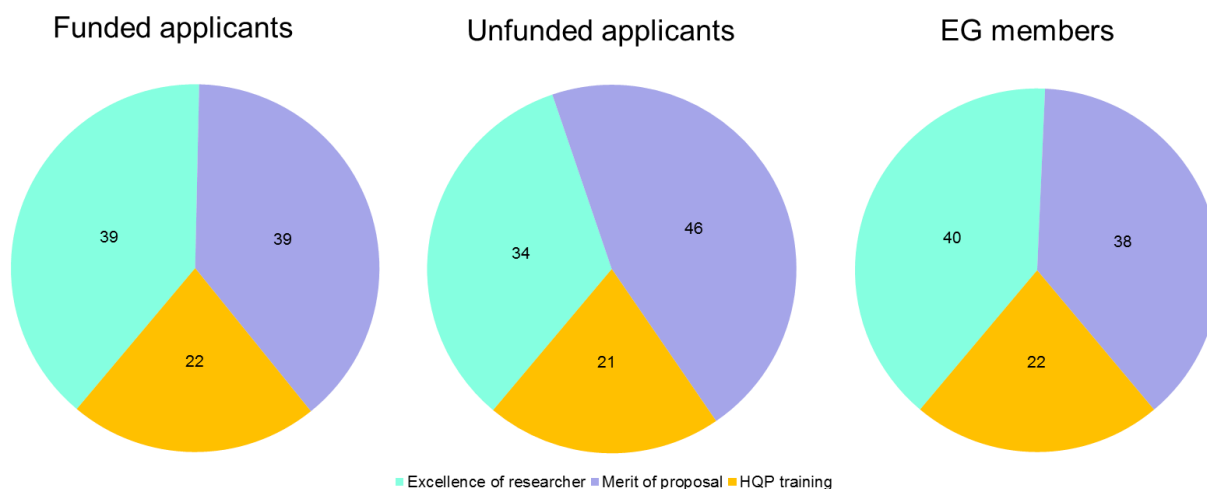
NSERC data show that roughly three-quarters of respondents (funded, unfunded and EG) believed that the current equal weighting of the excellence of the research, the researcher and training was inappropriate. By far the most common alternative weighting suggested was 40%, 40% and 20%, respectively. Weighting HQP training equally for ECRs was considered especially problematic, as these individuals have had little time to build a substantial training program. NSERC further noted that twice as many applications from smaller institutions fail because of the merit of the proposal criterion than because of the HQP criterion.

Figure 4. How much importance should be attributed to each of the selection criteria when a proposal is evaluated?



Sources: Survey of Discovery Grant applicants; survey of EG members

Figure 5. Other weighting proposed (mean of responses)



Sources: Survey of Discovery Grant applicants; survey of EG members

The Panel recognized that the criterion related to the training of HQP was difficult to interpret, as it does not clearly define whether NSERC’s goal is to train as many students as possible or to produce the best students. Panel members commented that, in fairness, HQP training – and especially the quality of that training – was almost universally the most difficult criterion to evaluate in similar international programs, with “reading between the lines” often being required (that is, NSERC and Discovery Grants are not unique in this). The Panel is not aware whether any better HQP metric is used internationally. Overall, this situation suggests that, since the HQP criterion is difficult to rate, this criterion is perhaps too heavily weighted in the current review process. This was not seen as a shift in priority, but rather as a potential refinement to the adjudication process.

Conclusions: The Panel agreed that the information requested in applications was relevant, appropriate and well-used. In particular, the excellence of the applicant and the merit of the proposal criteria were recognized by the Panel as appropriate.

Even the more difficult HQP metric was in line with international practice. However, as this metric is very difficult to define – in particular, how to judge the number of HQP versus the quality of training – the Panel recommended that NSERC review best practices used internationally to refine this metric if possible. If improvement to the metric is not possible, the Panel recommended that consideration be given to changing the metric weighting from 33% for each of researcher, proposal and HQP criteria to 40%, 40% and 20%, respectively. This revised weighting was the most common suggestion from the community; it would not change Bin distribution substantially and would show NSERC’s responsiveness to community input. The Panel recommended that, if the weighting is changed, NSERC communicate to the community that training has not been de-emphasized.

The Panel further recommended that NSERC consider whether the HQP metric should focus only on students and PDFs (i.e., not research associates or technicians) and consider coarser discrimination for the HQP metric (for example, by employing a four-point scale). Consultation with the Committee on Grants and Scholarships (COGS) and EG members on these points was suggested.

3.8 Use of the Research Cost Factor During Application Review

Evidence: Under the new system, all applications within a given quality Bin would normally receive the same funding. But since research costs may vary within a discipline, a “research cost factor” can allow EGs to slightly adjust funding for proposals that require more support. NSERC data show that only four or five of the EGs use this cost-adjustment tool. Some EG respondents noted that it is too complicated to use, that it does not provide enough extra funding to make a difference (e.g., in chemistry for infrastructure, or in earth sciences for field work), or that additional costs are expected to be absorbed by the applicant’s other sources of funding.

Conclusions: The Panel was unclear as to the value of the tool, but suggested leaving it in place for EGs that wished to use it.

3.9 Use of Budget Justifications During Application Review

Evidence: Since all successful applicants in the same quality Bin receive nominally the same Discovery Grant amount, there have been questions from the research community as to the need for and relevance of providing an estimated budget justification, especially given that the Discovery Grant is a grant-in-aid and most researchers expect to obtain additional program funding. NSERC noted that asking for budget details helps keep applicants realistic in their expectations, although it is difficult to build budgets for long-term programs in which the research may change dramatically over the course of the grant.

Conclusions: The Panel recommended continued inclusion of budget justification in applications. It was believed that the budget information is useful to demonstrate the applicant’s understanding of the detailed factors that influence research costs, and of managing and mitigating these costs. This information is also useful to demonstrate due diligence of NSERC to Treasury Board, and to allow NSERC and the community as a whole to understand the magnitude of the true costs of research.

4. Findings on Efficiency

4.1 Efficiency of the Discovery Grants Delivery Mechanisms

Evidence: A common measure of operational efficiency of grant programs is to assess the ratio of operating expenditures to the total amount of grant funds awarded. This ratio represents the cost of administering \$1 of grant funds awarded. The granting agencies also commonly report operating expenditures as a percentage of total program expenditures (i.e., operating expenditures plus grant expenditures).

At 4.3 cents for every \$1 of grants awarded over the five-year period, the administrative costs for the Discovery program are very low. These figures have remained relatively stable over time ranging from 4.3 cents in 2007-08 to 4.1 cents in 2011-12, with a one-time surge to 4.8 cents in 2008-09. This operating ratio is comparable to the overall operating ratio of NSERC over the same period at 4.7 cents for every \$1 of grants awarded. Administrative costs for Discovery Grants alone, presented in Table 7, have similar trends and are comparable to those of the broader Discovery program during this period.

Table 7. Estimation of Discovery Grants Operating Expenditures²⁰

Expenditures	2007-08	2008-09	2009-10	2010-11	2011-12	Total
Direct Salary	\$3,094,633	\$3,343,432	\$3,343,277	\$3,268,676	\$3,516,130	\$16,566,148
Direct Non-Salary	\$1,361,302	\$1,737,628	\$1,547,225	\$1,379,289	\$1,299,036	\$7,324,481
Total Direct	\$4,455,935	\$5,081,061	\$4,890,502	\$4,647,966	\$4,815,166	\$23,890,629
Indirect	\$8,488,445	\$9,276,215	\$8,379,948	\$9,029,833	\$8,617,794	\$43,792,235
Total Operating Expenditures	\$12,944,379	\$14,357,275	\$13,270,450	\$13,677,799	\$13,432,960	\$67,682,863
Grant Funds Awarded	\$309,590,465	\$312,011,106	\$317,263,250	\$314,500,327	\$318,220,553	\$1,571,585,701
Total Program Expenditures	\$322,534,844	\$326,368,382	\$330,533,700	\$328,178,126	\$331,653,512	\$1,639,268,564
Operating Ratio (¢:\$1) (Operating Expenditures to Grant Funds Awarded)	4.2¢	4.6¢	4.2¢	4.3¢	4.2¢	4.3¢
Operating Expenditure as a Percentage of Total Program Expenditures	4.0%	4.4%	4.0%	4.2%	4.1%	4.1%

Source: NSERC administrative data

The Panel was struck, however, by the extensive commitment required by EG participants. By NSERC's estimation, roughly three to four weeks of time is volunteered per EG member, and it is

²⁰ Operating expenditures include both direct and indirect costs of administering the program. Direct costs are comprised of salary and non-salary costs, which are related primarily to the adjudication of the award. Non-salary costs also include a share of the costs related to corporate representation and general administration of the Research Grants and Scholarships Directorate. Other direct costs associated with administering the program, such as post-award management (which is a centralized function carried out by the Finance division) and indirect costs, such as common administrative services for NSERC (e.g., finance, human resources and IT) have also been included in the total calculation of costs and were estimated using the ratio of total Discovery Grant awards to total NSERC grant funds.

becoming somewhat more difficult to recruit EG members. In total, there are over 8,000 individual reports from 4,500–5,000 external reviewers, plus more than 400 members of the EGs themselves. It is estimated that approximately 130,000 hours are spent in total on reviewing the Discovery Grant applications by EG members and external reviewers. Thus, each DG review cycle consumes roughly 48 person-years of time. This represents cost savings for the Federal Government since it is *pro bono* support provided to NSERC by volunteers. An estimate of the in-kind costs of this volunteer support ranges from approximately \$10 million per year (based on a remuneration of \$75 per hour) to as high as \$20 million per year (based on a remuneration of \$150 per hour).

Some international members of the Panel commented that this extensive commitment is made possible by the full-year salary support Canadian universities offer their faculty members. In the US, by contrast, faculty members receive no salaries from their university employers during the summer months and must rely on support from their research grants²¹. US faculty members were believed to be financially unable to volunteer the three to four weeks required for Discovery Grant-style reviews (although they make up the majority of international EG members).

Summary: The data showed that Discovery Grants administrative costs are low compared to program expenditures. Further, these costs appear to be in line with (or lower than) similar costs in other international programs. The Panel commented, however, that not counting the in-kind costs of volunteer reviewers underestimates the true level of effort of the peer review system. The Panel recommended that NSERC and COGS investigate whether increased efficiencies in this area could be found.

4.2 Impact of Changes to the Peer Review System on the Efficiency of the Discovery Grants

Evidence: Administrative costs for Discovery Grants have remained virtually constant from 2004–05 through 2011–12, implying no efficiency gains or losses from the new system. Although the travel costs associated with international EG members were trending upwards, this trend did not have any impact on the overall administrative cost ratio for the program as it was balanced by cuts in other administrative expenses. Within all NSERC programs international costs were trending downwards, as there is less use of reviewers far afield, from Australia, Asia, etc., and increased use of nearby researchers in the US, Europe, etc.

Conclusions: The Panel did not find any significant impact on delivery efficiency caused by changes to the peer review system.

It also found that the occasional use of international reviewers was consistent with best practices and that costs for this activity did not seem out of line. The Panel noted that the use of external reviewers requires considerable effort. As external reviewers see only a maximum of three proposals, as contrasted with the 40–50 applications read by EG members, their views do not reflect as broad a sample and thus may be inconsistent with the majority of EG reviews. Such inconsistency is often difficult for EGs (and applicants) to reconcile. However, these reviews yield the occasional “gem,” and the Panel recommended that mechanism should be kept.

²¹ Summer salaries are eligible grant costs in the US.

5. Conclusions and Recommendations

5.1 Relevance

Conclusions concerning the need for Discovery Grants and support for discovery research:

Discovery Grants represent NSERC's flagship funding opportunity, and is the only Canadian program explicitly supporting foundational research in NSE; there is clear evidence of the relevance and importance of Discovery Grants in this arena. Of particular note is its unique support for five-year individual programs of research, as opposed to the much more common support for shorter-term projects or teams. This feature of Discovery Grants is highly valued by Canadian researchers and admired by international investigators.

Another unusual feature is Discovery Grants' relatively high application success rate, which is seen to suit Canada well; the current balance between supporting a broad base of researchers and institutions and supporting excellence is generally very appropriate.

Review of similar international programs, however, suggests that Canada may be losing ground in terms of total funding for broad-based research and it is falling back in numbers of papers published (but not in quality of papers).

Discovery Grants provide the core "grant in aid" funding for most researchers' investigations and form a base upon which considerable amounts of additional research funding can be built (often called "leveraging") for foundational research in NSE. While the exact nature of "leveraging" remains unclear (it appears that Discovery Grants provide a "multiplier" or a "halo" effect), the Discovery Grant is perceived by the Canadian academic community as the cornerstone for building research programs, supporting trainees and maintaining laboratories. The ability to obtain a Discovery Grant is also seen as a mark of distinction in a researcher's career.

A high proportion of Discovery Grants funding is used to support HQP, and there is clear evidence that Discovery Grant holders support more HQP than researchers who applied for but did not receive a Discovery Grant. The Discovery Grant's five-year term is also an effective mechanism to support HQP in a sustainable manner.

The Panel concluded that Discovery Grants continue to be Canada's most important support mechanism for foundational research and should be fully recognized for this importance. Further, NSERC should keep the current balance between supporting excellence, broad support for research and training HQP. No major changes were recommended by the Panel — all further recommendations below reflect refinements to the existing system.

The Panel noted that Canada may be lagging somewhat behind international efforts in terms of the level of HERD in relation to GDP and suggested that Canada cannot afford to let HERD levels

remain static. Ideally, the Government of Canada should seek increased resources for the Discovery Grants.

Conclusions concerning support for high-risk research: The unique nature of the Discovery Grants allows pursuit of a portfolio of research activities, including high-risk research, without requiring a separate funding mechanism. Therefore, the DAS requires reconsideration because of difficulties associated with defining and assessing high-risk research and because high-risk research is supported to some degree already through Discovery Grants. Given the challenges faced by early-stage researchers, as evidenced by a low success rate and the lowest funding level, the Panel recommended returning DAS to its original intent of being an “accelerator” (beyond what Bin placement could achieve) but targeted towards early-stage researchers who, on their first application or renewal, demonstrate evidence of early successes. This will address challenges faced by early-stage researchers who continue to find it difficult to obtain a first Discovery Grant award and a first renewal because they have had little time to develop a high-quality research program, build up their laboratories and develop an HQP training program.

Recommendation 1: Refine the Discovery Accelerator Supplements. The intent and nature of the Discovery Accelerator Supplements should be refined. The Panel recommended:

- maintaining the Discovery Accelerator Supplements envelope as a separate allocation from Discovery Grants;
- altering the focus of Discovery Accelerator Supplements away from support for “high-risk” applications, and more towards its original “accelerator” intent, but in a more targeted fashion;
- targeting Discovery Accelerator Supplements funding towards early-stage researchers (e.g., up to 10 years after PhD) and first renewals, to accelerate support for those showing evidence of early successes in order to allow a firm start to a new career; and
- communicating this shift in focus clearly to the community (as the current “new” goals are still not well understood).

Recommendation 2: Allow early first renewal for early-stage researchers. The Panel recommended:

- increasing flexibility to allow early-stage researchers to apply early for a first renewal, at their discretion.
 - The funding recommendation of the Evaluation Group would be final, whether they were “normal” renewals after five years, or an early first renewal after three or four years.
 - Outcomes of first renewal applications would be monitored and reported separately from subsequent renewal applicants.
 - The Discovery Accelerator Supplements could be considered as a source of additional funding, following adjustments of its goals (see recommendation #1).

5.2 Effectiveness

Conclusions concerning the revised peer review system: The new conference model and two-part peer review system works well for members of the EGs and has increased the quality of the peer review process, especially for multidisciplinary and interdisciplinary proposals. The EG members generally understand the system well, are satisfied with the nature of applications they review and believe joint reviews across EGs are effective. There is some evidence that the entire community does not fully understand all details of the new conference model, however.

The changes have notably reduced the inertia associated with the previous system, as demonstrated by significantly increased scatter in the correlation of renewal Discovery Grant size with previous award amount. Especially striking is the increased number of “null awards” (i.e., unsuccessful applications). All available evidence suggests that the new Bin system appropriately discriminates among the quality cohorts of applicants and fosters excellence, as evidenced by the increases in research productivity and publication quality at higher Bin levels. The current Bin cut-off points for funding also appear appropriate, with no reason to change the cut-off points.

Although the Panel believed that NSERC could consider even further emphasis on excellence at the expense of broad support, no significant change was recommended, and this belief was not unanimous among Panel members.

Apart from a potential for training disruption when an established researcher obtains a significantly decreased renewal (especially a “null award”), there is no evidence of significant unintended impacts of the changes to the peer-review system that were introduced in 2009 and 2010. However, refinements might be made in support for early-stage researchers, as noted above. NSERC’s existing efforts toward ECRs²² have been positive but could be expanded to consider a longer period as they establish their careers. For early-stage researchers on a “fast track” to success, it would be beneficial to allow early first renewals to help accelerate their careers.

Recommendation 3: Make small refinements to the peer review process. The Panel recommended:

- better communicating how the conference model works with regard to how the review of interdisciplinary applications is conducted; and
- considering ways to provide more and better feedback to Discovery Grant applicants, especially those who received lower (or null) awards.

Conclusions concerning the research cost factor and application budget information: The research cost factor is used to varying degrees according to the needs of individual EGs; although not of critical importance, it is occasionally useful. The budget justifications in Discovery Grant applications are useful for assessing the eligibility of requested cost items, to help demonstrate NSERC’s due diligence to Treasury Board and to help understand the true costs of research.

²² As noted earlier, NSERC guidelines define ECRs as researchers who are within two years of their first eligible academic appointment but without prior independent research experience. The Panel defined early-stage researchers more broadly as being researchers within 10 years of their PhD.

Recommendation 4: Retain use of the research cost factor and application budget information. The Panel recommended:

- retaining the cost of research adjustment tool, which is used to alter grant amounts modestly within funding Bins, for those Evaluation Groups that wish to use it to adjust for differential costs; and
- continuing to require budget justification in applications.

Conclusions concerning the metrics used to review Discovery Grant applications: The current criteria for proposal review are appropriate and work well for the EGs, although NSERC struggles somewhat with defining the HQP criterion and assessing the contribution to HQP training. The Panel suggested that NSERC review best practices used internationally to define this criterion and refine it if possible. If improvement to the criterion is not possible, the Panel recommended investigating a change in weighting among these criteria to slightly de-emphasize the HQP metric, while strongly communicating to the community that this did not imply less emphasis on the training itself.

Recommendation 5: Consider revising the HQP criterion. The Panel recommended:

- maintaining the three criteria currently used to review Discovery Grant applications, but considering revising the criterion for contributions to training of HQP;
- reviewing international programs for best practices with respect to assessing HQP training in order to identify opportunities to improve the definition of this criterion; for example, considering whether the HQP criterion should focus only on students and PDFs (i.e., not research associates or technicians);
- consulting the Committee on Grants and Scholarships, as well as the Evaluation Groups, on how to improve the assessment of the HQP criterion and on communicating to the community;
- if a better HQP metric cannot be developed, consider revising the current weighting of the three Discovery Grants assessment criteria from 33% each to 40% (excellence of the researcher), 40% (merit of the proposal), and 20% (training of HQP). This was the weighting most commonly suggested by the community, and which would not significantly change Bin distribution; and
- if the weighting is changed, communicating that training has not been de-emphasized in any way, but continues to be a core goal of NSERC and Discovery Grants.

5.3 Efficiency

Conclusions concerning efficiency: NSERC's administrative costs were seen by the Panel to be low relative to the total amount of grant funds awarded, and in line with (or lower than) similar costs in other international programs. The new peer review system has not affected NSERC's efficiency in any way. However, the Panel noted that there was a substantial volunteer burden associated with reviewing Discovery Grants proposals.

Recommendation 6: Investigate additional efficiencies in the review process. Some Panel members believed that it may be possible to reduce the high EG workload. The panel recommended:

- consulting with the Committee on Grants and Scholarships to review the models of other agencies and countries to identify opportunities for increased efficiencies.

APPENDIX A:

Composition of the International Review Committee

Dr. Max Blouw

President

Wilfrid Laurier University

Canada

Dr. Murray Campbell

Senior Manager, Business Analytics Research

IBM Thomas J. Watson Research Center

US

Dr. Marie D'Iorio

Executive Director

National Institute for Nanotechnology

Canada

Dr. Philippe Freyssinet

Directeur Général Adjoint

Agence nationale de la recherche (ANR)

France

Dr. Larry Mayer

Professor and Director, Center for Coastal and Ocean Mapping

University of New Hampshire

US

Dr. Richard de Neufville

Professor of Civil and Environmental Engineering

Massachusetts Institute of Technology

US

Dr. Alison Sekuler

Associate Vice-President and Dean, Graduate Studies

McMaster University

Canada

Invited Researchers

Dr. Tony Vanelli,

Dean of Applied Sciences,

University of Guelph

Dr. Barbara Sherwood Lollar,

Professor and Director, Stable Isotope Laboratory

University of Toronto

Dr. Vida Dujmovic

Assistant Professor,

Carleton University

APPENDIX B:

Data Available to the International Review Panel

Data from a wide variety of sources were made available to the Panel, including:

- Survey of Discovery Grant applicants. Discovery Grant applicants who applied in 2009-2012, as well as Discovery Grant recipients who applied prior to 2009 but whose awards were still active at the time of evaluation, were surveyed. The survey explored the issues of program relevance (e.g., the role of Discovery Grants in funding research programs; impact of Discovery Grants on the ability to attract research funding from other sources; the role of the Discovery Accelerator Supplements (DAS) in supporting high-risk research, etc.); design and delivery (e.g., researchers' perceptions with regard to the EG structure and the current weighting); and effectiveness (e.g., researchers' perceptions of the impact of the changes in the peer-review system on funding for researchers and fostering research excellence, importance of providing research training to HQP, etc.). The number of respondents to the survey is as follows:

- Researchers who received a Discovery Grant in 2009-2012 (n=3,921);
- Researchers who applied for a Discovery Grant in 2009-2012 but were not successful (n=895);
- Researchers who applied prior to 2009 and whose awards were still active (n=1,269).

The response rate for the survey of applicants was 45.9% with the margin of error being $\pm 1.1\%$.

- Survey of the EG members who participated in application reviews since 2009 (n=395). The survey explored the current practices with regard to the review of Discovery Grant applications (e.g., elements that are mostly taken into consideration when reviewing applications), EG members' observations pertaining to the effectiveness of the current peer-review system, as well as potential ways to further improve the peer-review process. The response rate for the survey of EG members was 47.8% with the margin of error being $\pm 3.6\%$.
- Interviews with the current and former EG Chairs and Section Chairs (n=27). The interviews explored areas and questions similar to the survey of EG members and provided a broader descriptive context.
- Administrative data review:
 - File review of all Discovery Grant applications submitted in 2010 (competition year 2011). The file review aimed to identify the sources of funding, other than Discovery Grants, of researchers' overall funding.
 - Review of administrative costs. The review examined the costs associated with the delivery of Discovery Grants and the efficiency of the funding opportunity.
 - Review of the Statements of Account (Form 300). The review explored the proportion of Discovery Grants funding dedicated to supporting highly qualified personnel.
- Consultations with scientific societies and university administrators. NSERC invited 66 scientific societies and organizations to consult their membership, as appropriate, and provide responses to 5 questions; 32 submissions were received. The purpose of the consultations were to obtain feedback from scientific societies and university administrators regarding: the role that Discovery Grants should play in funding NSE research; the extent to which the focus and objective of the Discovery Accelerator Supplements are appropriate; the perceived appropriateness of the existing

selection criteria; as well as the ability of the current peer-review system to ensure consistency and fairness in the assessment process and enable meritorious applicants to increase their funding more quickly.

- Document review explored the extent to which the Discovery program is aligned with Government priorities.
- International comparison study explored the funding strategies of six other countries (i.e., Australia, China, Finland, Germany, Singapore, and the UK) in support of basic research and how they evolved since 2007. The extent to which features of Discovery Grants' approach and model are becoming more evident within the strategies of other countries was also explored.
- Bibliometric / citation analysis related to Canada's performance in NSE disciplines. The bibliometric study explored the issues pertaining to program relevance (comparison of Canada's NSE publications and their quality with other countries, as well the support from Discovery Grants to Canadian publications) and effectiveness (the extent to which Discovery Grants and DAS had an impact on researchers' performance).
- Presentations to the panel by three guest researchers (Discovery Grant recipients) at differing stages of their career and administrative responsibilities were invited to provide the panel with their first-hand experience and perspective of Discovery Grants (see Appendix A).

APPENDIX C:

Limitations and Mitigation Strategies

Overall, the Panel believed the methodology is strong in providing the basis for reaching conclusions for all issues and questions using multiple lines of evidence. The primary strategies employed to ensure reliability of evaluation findings involved the following.

- *The International Review Panel.* NSERC convened an international panel to assess the extent to which Discovery Grants were meeting the objectives relative to support for research in the natural sciences and engineering (NSE) in Canada. The members of the Panel hold senior positions as researchers or administrators within Canadian and foreign universities, research funding agencies, government departments or in the private sector. The Panel provided broad perspectives of the NSE fields both in Canada and abroad, and added a level of objectivity when validating the evaluation findings and drawing conclusions and recommendations.
- *Multiple lines of evidence.* Multiple lines of quantitative and qualitative evidence were used to consult stakeholder groups (surveys, interviews, administrative data review, consultations, and bibliometric study) as part of the evaluation. Where possible, findings from different lines of evidence were compared and contrasted to draw findings and conclusions. Qualitative as well as quantitative feedback was obtained from stakeholders through the surveys, interviews, and consultations.
- *Comparison group.* The survey of unfunded applicants served as a comparison group for funded applicants. This ensured that the views of recipients were balanced with those of non-recipients regarding perceptions of the impact of changes in the peer-review system, as well as program design and delivery. The same comparison group was also used in the bibliometric study. This permitted a comparison of funded and unfunded applicants with respect to their research productivity and quality of publications.
- *Census of funded and unfunded applicants and use of weighting to mitigate response bias.* The surveys of funded and unfunded applicants were based on a census of all applicants to the program between 2009 and 2012. The survey also included those researchers who applied prior to 2009 and whose awards were still active at the time of evaluation. Respondents to the survey were compared to the original sample for differences, and weighted to remove any potential bias resulting from these differences. A high response rate (45.9%) with a low margin of error ($\pm 1.1\%$) also helped mitigate any potential response bias.
- *Inclusion of different stakeholder groups.* The evaluation consulted a number of different respondent groups on key evaluation issues, including funded and unfunded applicants, representatives of scientific societies, university administrators, and Evaluation Group members.

Notwithstanding the strength of the methodology, there are limitations associated with some lines of evidence. These limitations were carefully considered when conducting the analyses. The limitations and mitigation taken to address these include:

- *Potential response bias.* Some respondent groups consulted as part of this evaluation (e.g., funded researchers) have a vested interest in Discovery Grants. As such, their responses are potentially biased toward favourable program outcomes. In the same vein, responses of applicants whose funding was reduced or terminated under the new peer-review system are potentially biased towards negative perceptions of the changes. This limitation was addressed

by conducting comparative analyses for some questions for different groups of applicants and by the triangulation of other lines of evidence during analysis and reporting.

- *Limits to qualitative methods.* In interviews and consultations a limited number of respondents were consulted. As a result, findings may not be generalizable to the broader population of stakeholders (e.g., university representatives, Evaluation Group members). This limitation was addressed by the triangulation of qualitative and quantitative lines of evidence in reporting (e.g., balancing the interview data of Evaluation Group Chairs with the survey data of Evaluation Group members).
- *Timing of the bibliometric study.* Supported papers are lagged two years relative to the funding amount and the population of researchers in a given fiscal years. This time lag is used to account for typical delays between the funding receipt/execution of work and the publication of scientific results. Due to this time-lag, data on the number of supported papers in Fiscal Year 2010 were incomplete (2012 papers were not fully indexed in the Web of Science database at the time the data was produced) and those in Fiscal Year 2011 were not yet available. The conclusions related to the bibliometric study were drawn based on the information available, which did not include the full cohort of researchers funded since 2009. To address this limitation, the bibliometric results are triangulated with other qualitative and quantitative lines of evidence in reporting where possible.