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Evaluating Program Fit

A case study of Genome Canada programming, 2000-11

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Abstract

This paper assesses the fit between project allocations and the strategic objectives of Genome Canada (GC), a major research funder in Canada. A regression model was used to test the relationship between the objectives of the organization (using data available to decision makers) and the share of funds allocated to specific projects, both in the total pool of investments and open competitions. The overall fit between 2001 and 2011 was about 35%, with the impact factor of the principal investigator being the most significant driver. The fit decreased for the open competitions alone, suggesting directed investments more strongly fit organziational goals.

Key Words

Evaluation; research management; Genome Canada; program assessment.

Introduction

Genome Canada (GC) is an independent non-profit organization established in April 2000 that provides funding, coordination and information resources for genomics and proteomics research in Canada. GC targets the development and implementation of large-scale research projects in key bio-science areas (health, agriculture, environment, forestry, fisheries, mining and energy) to help Canada become a world leader in genomics and proteomics research, as well as in the promotion of the ethical, environmental, economic, legal and social (GE^3LS) aspects of genomics research.

GC is designed to effectively translate research results into broader commercial outcomes, through the funding and management of large-scale interdisciplinary and internationally peer-reviewed research projects along with S&T (science and technology) Innovation Centres. GC operates in close collaboration with its primary partners—the six Genome Centres representing British Columbia, Alberta, the Prairies, Ontario, Quebec, and the Atlantic region. The relationship between GC and each of the Genome Centres is defined by means of a funding agreement that "not only acknowledges the independence of each Genome Centre, but also specifies the parameters in which each Centre is to operate and contribute to GC's overall mandate" (KPMG 2009).

This paper reviews the basic theory of evaluation, reviews the background on Genome Canada investments decisions and undertakes an economic evaluation of the fit between the visible evaluation criteria and the investment decisions.

Policy and Program Evaluation

Evaluation is a critical part of the public policy system, as it helps to define problems, delimit options, aid with decision making and improve operational efficiency. Evaluation is defined as the systematic determination of merit or worth using criteria against a set of standards. At the organizational level, evaluation is a critical link in Simon's (1997) ends-means causal chains. For organizational evaluation, the focus is on how specific activities or processes contribute to the goals of the institution or agency.

The design of a particular evaluation approach depends on the actors involved and the situation. Standards and principles of evaluation provide some sense of direction, along with the base of ethical norms, commitment and integrity. In our study, the stated objectives of GC are the foundation of the whole process for project evaluation.

In an early paper on performance evaluation, Arvidsson (1986) focuses on the pressures facing public services, expressing that government performance evaluation could be measured in several ways, by examining objectives, timing and the procedures of administration. King (1987) asserts that research evaluation "makes use of a variety of indicators to draw as complete a picture as possible of the complex aspects that account for the performance of research."

Rossi et al. (2004) defined program evaluation as the use of social research procedures to systematically investigate the effectiveness of social intervention programs, adapted to the political and organizational environments and designed to inform social action in ways that

improve social conditions. Comprehensive evaluation is an assessment of a program that covers the need for the program, its design, implementation, impact, and efficiency.

The differences between policy analysis and policy evaluation are widely known but often unrecognized. Geva-may and Pal (1999) compare policy evaluation and policy analysis in terms of concept, methodology, problems and data description. Evaluation tends to adopt a focus on the process which is being used to make policy choices.

Theory-based evaluation (TBE) has become widely discussed and occasionally practiced in the recent years. Birckmayer (2000) identified evaluations may be needed beyond operational assessment. Supporters think this approach will help to explain how and why formal project assessments predict the results. Very often, this type of evaluation will follow each step in a sequence to see whether the expected steps actually occurred.

One way to look at the challenge of evaluating research systems is through an outcomes management framework, such as used by the Treasury Board of Canada – in this context, evaluation could focus on efficiency and effectiveness, with efficiency analysis investigating the causal path between inputs, activities and direct outputs. With respect to GC, the inputs could be translated as the allocation of funds from Industry Canada. The focus of this work is on the 'activities' undertaken by GC to allocate funds to specific science projects (the outputs).

Luukkonen (2002) notes that research evaluation is also connected with the assessment of applicant performance and on the embedded decision-making sub-systems, such as peer review.

Patton (2002) explains,

> [A] successful evaluation emerges from the special characteristics and conditions for a particular situation—a mixture of people, politics, history, context, sources, constraints, values, needs, interests, and chance. Despite the rather obvious, it is not at all obvious to most stakeholders who worry a great deal about whether an evaluation is being done right. Indeed, one common objection stakeholders make to getting actively involved in designing an evaluation is that they lack the knowledge to do it right.

In essence, performance evaluation is described as comparing results against objectives, which will vary with different situations. It could also be applied in many ways. Ruegg and Jordan (2007) offer a range of evaluaiton methods, including: benchmarking; surveys; technology commercialization tracking; historical tracing; case study; peer review/expert judgment; tracing; network analysis; benefit-cost case study; and econometric modelling.

A critical part of any effective public policy assessment is to compare activities and outputs against the proposed goals and objectives of the initiative. In most cases, the outputs are assumed to conform to the stated goals and objectives but are not assessed as part of a formal evaluation.

Background on Genome Canada Investments and Evalution

While GC has undergone organizational, administrative and financial reviews, it has not undertaken any specific evaluation of the process of targeting its operating model to realize its stated goals. This project explicitly assesses the choices made by GC in the context of its funding competitions to determine how the organizational goals are reflected in the projects selected.

GC identified five key objectives to help move Canada onto the world stage in its 2007 corporate strategic plan (Genome Canada 2008). Specifically, the organization seeks to:

1) Develop and implement a coordinated strategy for genomics and proteomics research.
2) Support large-scale genomics and proteomics research projects of strategic importance to Canada, by bringing together industry, governments, universities, research hospitals and the public.
3) Provide accessibility to Science & Technology Platforms to researchers in all genomics and proteomics related areas through six regional Genome Centres across Canada (Atlantic, Québec, Ontario, Prairie, Alberta and British Columbia). The relationship established between GC and each of the Genome Centres is defined by means of a funding agreement that not only acknowledges the independence of each Genome Centre, but also specifies the parameters in which each Centre is to operate and contribute to GC's overall mandate.
4) Encourage external investment in the fields of genomics and proteomics, attracting co-funding for projects from both domestic and international investors.
5) Sustain leadership in research areas on ethical, environmental, economic, legal and social issues related to genomics and proteomics research, and promote the communication of the relative risks, rewards and successes of genomics and proteomics research to the Canadian public.

GC has developed a detailed operational process for determining its allocation of funding. While the order of the early steps in each competition might vary, all of the competitions have followed a common path.

First, after consultation with industry, government, the scientific community and end-users, (sometimes informally and sometimes through the use of formally structured theme papers), GC frames a funding request for Industry Canada that states what area the organization will focus on and what the money will be used for. If successful, GC then devises competition objectives. Most federal requests are only partially awarded.

Second, GC issues a call for proposals, which articulates the focus and scale of projects that could be funded. In most cases letters of intent are first reviewed and in a few cases have been used to triage the proposals. Projects are evaluated and invited to submit full proposals. Full proposals for the open competitions are peer-reviewed and assessed by panels of international reviewers, which rank the proejcts for funding. The GC Board then approves the allocations. Each approved project embodies milestones that trigger quarterly progress reports and a final statement of activities and outputs.

In the context of this effort, GC regularly undertakes audited financial reporting, has engaged in organizational and process evaluations and has assessed the outputs of the

competitions. To date, GC has used a range of these methods. The most prominent choices have been document review, peer review (used for Competition I, II, III, ABC) and case study. The KPMG Evaluation of Foundations evaluation team reviewed a broad range of documentation on the government's use of foundations to achieve policy goals, the evolution of the terms and conditions under which foundation funding has been provided, and the results achieved by various foundations. The team also undertook case studies to obtain insights into the appropriateness, effectiveness and costs of specific foundations. KPMG's review in 2009 used a mixed method approach, including peer-reviewers, expert judgment, survey and benefit cost. So far, the organization has not assessed the efficacy and appropriateness of the funding allocation decisions and their fit to the organization's mandate and objectives.

As of 2012 GC had committed $915 million in funding and researchers had secured approximately an additional $1,085 million in co-funding, representing a total investment of over $2 billion in completed or planned genomics research in Canada. All these investments have laid a foundation for a rich, vibrant genomics research community in Canada, and as noted below, have transformed the quantity, scope, scale and quality of such research (KPMG 2007).

The overall efforts of GC can be summarized by the following: $2 billion invested, with more than half secured from partners; 156 large scale research projects across the life science sectors; six world-class S&T Innovation Centres; more than 200 project leaders, who have developed the skills to manage complex science knowledge into application; more than 4,500 research publications, contributing to raising Canada to the top five in the world in the world in terms of scientific impac, and fourth in research related to science and society; more than 20 companies created; more than 10,000 highly skilled people trained and employed; and more than 350 patent applicants/awards, and 24 license agreements, placing Canada first in the multi-criteria ranking for intellectual property in genomics in 2005–2007 (Genome Canada 2012).

As shown in table 1, GC has engaged in four large-scale, open research competitions, commonly named competitions I, II, III and the applied genomics in bio-products and crops (ABC) competition. The rest of the funding allocations were to directed projects/programs (called 'other' in this study) that were more directly managed and coordinated by GC or the genome centres.

Table 1: Genome Canada large-scale open competitions

	Start Date	**Total approved budgets**	**Number of approved projects**
Competition I	April 4, 2001	$136 million	17
Competition II	July 19, 2001	$155.5 million	33
Competition III	July, 2004	$346 million	33
ABC	April, 2008	$112 million	12
Total		$749.5 million	95
Source: Calculation from Genome Canada Corporate plan 2011-2012, Ottawa, 2012.			

GC has been extensively reviewed. In 2007 KPMG prepared an Evaluation of Foundations report for the Treasury Board Secretariat, presenting the findings of an evaluation of the use of foundations (i.e. special operating enterprises) as instruments of public policy. This study examined six foundations, including GC, and was conducted by KPMG LLP on behalf of the Government of Canada between September 2006 and January 2007 (KPMG 2007). The evaluation team started with a review of the government's use of foundations to achieve policy goals, the evolution of the terms and conditions under which foundation funding was been provided, and the results achieved by various foundations. KPMG reported on three aspects of the government's use of foundations. First, they examined the appropriateness of the foundation model as an instrument of public policy, concluding that the model exhibited generally strong degrees of alignment with the guiding principles published in Budget Plan 2003 (Department of Finance 2003). Second, they examined the effectiveness of the foundations, reporting on their progress against objectives, coordination with related government programs, alignment with government policy goals and their accountability mechanisms. The general conclusion was that the foundations were doing well on all measures, albeit with some range of effectiveness. Third, KPMG examined the operating and administration cost structures, focusing on structured and transparent processes for reviewing and selecting projects to support, and supporting systems for project tracking and financial management. The conclusion was that operating and administration costs are driven by needs to efficiently manage project workloads and to provide timely support for governance and accountability requirements. Foundation resource levels and costs appear to be closely matched to, or follow, the trends in the project workloads. In effect, KPMG offered an organization and operational review of the processes and structures, but did not undertake any specific analytical assessment of the fit of those processes to the overall goals or objectives of the organizations.

In 2008 KPMG was contracted by GC to do an overall evaluation of the impact of GC investments. GC is directed to undertake an evaluation every five years as a requirement of their funding agreement with Industry Canada. This evaluation focused on the impact of the funding allocations. The methodology involved a review of internal documentation and databases, web-based surveys and interviews and a partial cost-benefit analysis of GC research investments and outcomes. As an outcomes-based approach, the analysis did not directly assess the fit between the research funding decisions and the strategic goals of GC.

In 2008, GC articulated a full performance, audit and evaluation strategy (PAES). The strategy was developed as a high level framework which addresses key elements that GC had implemented or planned to put in place to ensure accountability in the achievement of objectives from the perspective of performance, audit, evaluation and reporting. These processes are designed to contribute to more effective operations and to ensure compliance to the funding agreements signed with Industry Canada with respect to the use and accounting of funds received from the federal government. GC also signs individual funding agreements with each of the six Genome Centres, where the undertakings agreed to with Industry Canada are carried out.

The PAES is comprised of three key frameworks: 1) performance monitoring and measurement; 2) audit; and 3) evaluation. All elements provide a foundation for strengthening internal management.

While these efforts to assess the operations of the organization address its goals and objectives, this work has been mostly in the form of institutional audits and qualitative assessments. This study extends that work. It offers an empirical, quantitative assessment of the fit between the institutional goals and objectives and the funding allocations of the organization to determine the relative balance and impact of the diverse objectives on their core activity of funding research.

Methodology, Model & Data

This section explains the logic for assessing the operational fit between Genome Canada's investment program between 2001 and 2012 and the organizational mandate. The hypothesis is that there should be a positive and significant fit between the objectives and the direction of the funding allocations. The goal is to undertake a strategic analysis of the GC funding allocation process. The logic of this process is laid out in Figure 2.

The funding agreement between the Government of Canada and GC lays out the organization's objectives. Those objectives are taken as high level criteria by which GC will allocate the funds provided by the government, whose overall science and technology policy direction is the production of scientific knowledge and the advancement and commercialization of technical knowledge.

From 2000 to 2012, the overarching goals of GC were: (1) developing and implementing a coordinated strategy; (2) bringing together industry, governments, universities, research hospitals and the public to support large-scale genomics and proteomics research projects; (3) providing accessibility to Science & Technology Platforms to researchers; (4) assisting in attracting co-funding for projects from both domestic and international investors; and (5) sustaining leadership.

These goals then translate into five core objectives that should be reflected in the funding allocation decisions:

- Objective 1 is to develop and implement a coordinated genomics research strategy. In practical terms, this translated into a series of internal processes to assess and identify coordinated strategies for genomics research to enable Canada to become a world leader in areas such as health, agriculture, environment, forestry, fisheries, technology and GE^{3}LS.
- Objective 2 is about providing leading-edge technology, in particular to researchers in all genomics-related fields.
- Objective 3 is to support large-scale research. Given the nature of the publicly-available GC database, which does not include the projects that were rejected, it is not possible for this study to show the effect of scale. One way to consider scale is to compare GC funding allocations with allocations on genomics-related research by the Canadian Institutes for Health Research (CIHR) and the Natural Science and Engineering Research Council (NSERC). The average size of GC allocations are about 10 times the size of the average CIHR grant and about 65 times larger than comparable awards by NSERC (Zhang 2014).
- Objective 4 is to assume GE^{3}LS leadership and to communicate more effectively with Canadians. This can be assessed by the role and position of GE^{3}LS in the structure of each competition and in the related projects.

- Objective 5 is to encourage investment by others. In practice, this can be measured by determining whether the projects leverage co-funding from non-governmental sources, including international sources (Genome Canada 2012).

The purpose of our study is to explore the influence of key factors in the selection and allocation of funds to projects. While the ultimate concern is the efficacy and accountability of the choice systems used by GC, the key processes are not directly measureable—they are effectively in a black box. Nevertheless, they are indirectly discernible through examining the information available at the time of decision-making and the resulting allocations of funds.

An econometric approach was used to fit proxies for the stated objectives to the share of the portfolio allocated to each project. A series of regressions is used to determine the proportion of the funding allocations that are explained by the objectives. The residual could be interpreted as the influence of soft factors, like the personal preference of the reviewers and GC staff, the cognitive bias of the various decision makers, the context of the specific science platform and the uncertain environment.

The basic equations in the model involve running regressions with the allocation decisions as the dependent variable and the key organizational and program objectives as the independent variables. The basic estimation equation is:

$$Y = a + b_1 * GE^3LS + b_2 * \textit{Technology} + b_3 * \textit{International co-funding} + b_4 * \textit{PI reputation} + b_5 * \textit{Institution research intensity} + b_x * \textit{Competition, section and regional dummies}$$

Two dependent variables have been tested, that is Y_1 (*GC-total*) and Y_2 (*open-comp*). The regression using the total pool of investments provides insights into the performance of the organization across the entire portfolio of investments (Table 2). This portfolio is chosen through two discrete systems. The main portion of the funding is allocated through open competitions, where investigator-led teams submit competitive proposals that are adjudicated through a competitive peer-review process. The rest of the portfolio involves directed projects, where GC, one of the regional centres or a partner has developed a project to fit a specific strategic or tactical need. These projects are internationally peer-reviewed but there is little in the way of competition in the process. The second regression tests to see how the choices in the open competitions conform to the objectives of GC. Any difference in fit between the open competitive process and the overall pool would provide some information about the efficacy of the process of developing directed projects.

The percentage share of each project in the total fund pool is a way to measure the allocation of funding. Each project will share Yr% of the funding pool in both the total and open competitions. The dependent variable Y_1 (*GC-total*) is the percentage share of GC contribution of each project in the total fund pool of all GC contributions. This pool involves 156 projects which shared $683 million invested by GC. It is calculated as the GC contribution dollar of each project (Ai) as a percent of the entire portfolio. While GC has invested $996 million, about one-third of the commitments and disbursals is for infrastructure and operations and not to fund research projects.The dependent variable Y_2 (*open-comp*) is the percentage share of the GC contribution of each project in the open pool of GC contributions in Competitions I, II, III and

ABC. From the calculation, we know that the total open pool $\sum_{i=1}^{m}$ Ai (i~[1,95], m=95) equals $485 million. Ai is the GC contribution of each project.

Table 2: Explanations of dependent variables					
GC-goals Objective	**Variable**	**Unit**	**Description**	**Calculation**	**Source**
Allocation of Fund	Y_1 (*GC-total*)	%	% share of GC contribution of each project in the total fund pool of all GC contribution	Ai/ $\sum_{i=1}^{n}$ Ai (%) (i~[1,156], n=156)	Genome Canada Reports[1]
	Y_2 (*open-comp*)	%	% share of GC contribution of each project in the open pool of GC contributions in I, II, III and ABC competitions.	Ai/ $\sum_{i=1}^{m}$ Ai(%) (i~[1,95], m=95)	

Table 3 shows the variables to represent the key objectives.

Table 3: Explanations of independent variables					
GC-goals Objective	**Subject**	**Unit**	**Description**	**Calculation**	**Source**
(a) Sustain leadership and coordinated strategy	X_1 PI (lead Harzing index)	Index	Principal Investigator (PI) research capability: measured by HI index (collected 2012.7)	Lead Harzing Index-HI Index	www.harzing.com
	X_2 Research intensity	$10K	Host institution research capability measured by total research funds/ per full-time faculty	Total Research Dollars ($10,000 per full-time faculty member)	*Maclean's* University Ranking
(b) Support GE3LS	X_3 GE3LS		Whether the project supports GE3LS	Yes=1; No=0	Genome Canada Reports [1]
(c) Encourage P3s	X_4 International co-funding		International co-funding source	Yes=1; No=0	
(d) Provide leading-edge technology	X_5 Technology		Does technology activity represent leading-edge?	Yes=1; No=0	

- PI and Research Intensity as a measure of Leadership: The coordinated genomics research strategy is designed to support leadership, which for this analysis is represented by the Principal Investigator's (PI) research capability measured by the Harzing Index (HI) (X1). The HI index (X1) was proposed by Hirsch (2005) and aims to measure the cumulative impact of a researcher's output by looking at the amount of citations among the most highly cited parts of his/her work. The calculation tool Publish or Perish calculates and displays the h index, its associated proportionality constant a (from Nc,tot = ah2), and the rate parameter m (from h ~ mn, where n is the number of years since the first publication).
- Given that one of GC's objectives is to generate globally competitive research capacity, it is be appropriate to assess whether prior institutional capacity is influential in determining the allocation of funds. The relative research intensiveness of the host institutions, as measured through the *Maclean's* institution research reports (X2) is one way to rank the host institution research capability. The annual *Maclean's*[1] rankings assess Canadian universities on a range of performance indicators in six areas. We chose the Total Research Dollars reported in *Maclean's* (including income from sponsored research such as grants and contracts, federal, provincial and foreign government funding, and funding from non-governmental organizations) adjusted for the relative size of each institution (using a capitation formula based on full-time faculty). The research capability of the host institution was rebased to 10,000 dollars per full-time faculty member. The range of this variable is 0.43 to 3.51, with a mean of 2.51.
- GC seeks to generate leadership in GE^3LS and other issues related to genomics research and the communication of the relative risk, rewards and successes of genomics to the Canadian public (X_4). Projects can either embody integrated research ($INTERGE^3LS$) or can be stand-alone GE^3LS projects. This is a dummy variable with a value of 1 if GE^3LS is embodied in some way in the project and 0 otherwise. Of the 156 projects, 11 are stand-alone GE^3LS projects and 50 are $INTERGE^3LS$.
- GC established ambitious co-funding goals for their projects (Objective 5). The minimum threshold was 100% matching, in cash or in kind. All approved projects by definition met that goal. Over the past decade, GC has attracted $1 billion in co-funding to complement the $980 million committed by the Government of Canada (Genome Canada 2012). There is little difference in leveraging among projects except whether they have attracted international co-funding, which is signalled by a dummy with 1=yes.
- The variable Technology (X_5) aligns with the goal of providing leading-edge technology. We coded this variable based on GC's annual report, which determines whether the project is in the "technology category" (value of 1) or not (value of 0).

A range of regional, sectoral and competition dummies were used to help to differentiate the different aspects of the economy and the subject areas. Given that there were four competitions as well as directed investments, seven priority research areas and six geographic regions, it is possible that these contextual elements may have been a determining factor in the funding allocations. Table 4 shows how those factors have been converted into dummies. The only significant change was to combine Genome Alberta and Genome Prairie, on the basis that their activities were highly correlated. Genome Prairie, located in Edmonton, served the three

[1] http://tools.macleans.ca/ranking2008/selectindicators.aspx

Prairie Provinces until 2005, when Genome Alberta became an independent centre and Genome Prairie moved operations to Saskatoon. Since then they have collaborated closely on development and management of a range of successful projects, making it problematic to include them as fully independent contextual variables.

The sum of dummies for each category above is equal to one, as all variables cover all the possibilities in each category. For example, a project by definition must be in one of the regions (British Columbia, the Prairies, Ontario, Quebec and the Atlantic), sectors (health, agriculture, environment, forestry, tech, GE3LS) and Competition category (com1, com2, com3, ABC, Directed). To avoid over definition of the regression, at least one variable from each category is excluded in each regression. Zhang (2014) constructed a correlation matrix of all the behavioural variables and dummies and constructed t-tests to look for evidence of correlation. The regional dummies for BC and Ontario were negatively correlated, which was controlled for by leaving the Ontario dummy out of the regression. The fishery dummy was also significantly positively correlated with the Atlantic region; fisheries were combined with the environment to remove that concern. These two fixes solved all the significant correlations.

Table 4: Description of dummies

Part	Variable = 1	Description	#	mean	% of fund
Sector	Health		82	0.52	62.26%
	Agriculture		16	0.096	8.55%
	Environment	Environment, energy, fishery	19	0.09	15.53%
	Forestry		11	0.071	6.21%
	Technology	Providing leading-edge technology	18	0.115	4.14%
	GE3LS	Ethical, environmental, economic, legal and social (GE3LS) aspects	11	0.071	3.32%
Region	BC		40	0.256	22.64%
	Prairie	Alberta, Saskatchewan & Manitoba	21	0.134	15.61%
	ON	Ontario	52	0.339	37.06%
	Quebec		34	0.218	21.15%
	Atlantic		8	0.051	3.59%
Compe t-ition	com1	Competition I	17	0.109	11.82%
	com2	Competition II	33	0.212	21.43%
	com3	Competition III	33	0.212	29..99%
	ABC	Applied genomics research in Bio-products or Crops(ABC)	12	0.077	7.77%
	Directed competitions	Other categories	61	0.391	28.99%
Total			156		

Once the dataset was constructed, STATA (version IC/11.1) statistical package was used to estimate regressions. The OLS method is chosen to estimate the model for two reasons. First,

the lack of any obvious correlations between the independent variables suggests that the variables may be independently considered in the decision system. Furthermore, there was no obvious direction or effort to differentially assess and apply the independent variables in the decision system—i.e. GC does not direct specific weights be used nor does it provide any architectural design to the consideration of these variables. All variables are considered equally in the decision system, with weights being revealed through choice rather than assigned a priori. Thus, in absence of any other evidence to the contrary, the OLS was chosen as the most appropriate method of calculating the influence of these variables on the overall decisions.

Empirical Analysis

This section presents and discusses the multivariate model results. The goal of the model is to quantify the relationship between the goals and funding allocations of GC. Table 5 presents the results of estimating OLS with Y_1 (*GC-total*) as the dependent variable. Four separate regressions are presented; models B-D add additional dummies to test for structural explanations for the allocations.

Table 5: OLS estimation result for Y_1 (*GC-total*)				
Dependent Variable Y_1 (GC-total)				
Independent Variable	**Model A**	**Model B**	**Model C**	**Model D**
Intercept	0.21	0.16	0.18	0.32**
Leadership indicators (PI-HI)	0.01***	0.01***	0.01***	0.02***
Research intensiveness (Maclean's research index)	0.06	0.03	0.02	0.007
Partnerships (International co-funding)	0.23***	0.2**	0.2**	0.21***
Integ-GE3LS	0.26***	0.25***	0.26***	0.19**
Dummy: Health sector		0.3***	0.3***	0.26***
Dummy: Ontario			0.05	0.07
Dummy: directed competition				-0.41***
Number of observations	155	155	155	155
F Statistics	7.75	9.97	8.33	12.80
Adjusted R^2	0.15	0.23	0.22	0.35
Significance levels (*p* value): * p<0.1; ** p<0.05; *** p<0.01				

Model D in Table 5 has the highest R^2. The basic equation of this model is as follows:

$$Y_1 = \underset{(2.40)**}{0.32} + \underset{(4.69)***}{0.02*(PI)} + \underset{(0.14)}{0.007*(Research)} + \underset{(2.77)***}{0.21*(International)}$$

$$+ \underset{(2.51)**}{0.19*(INTERGE^3LS)} + \underset{(3.79)***}{0.26*(Sector\text{-}health)} + \underset{(0.92)}{0.07*(Region\text{-}ON)} - \underset{(5.46)***}{0.41*(Directed)}$$

The intercept term is equal to 0.32, which means the funding share of a project in the total fund pool of competitions when the value of all other independent variables are equal to zero would be 0.32% (significant at 95% level). The reputation of a project's Principal

Investigator (PI), measured by the HI index, increases the project share by just 0.02% for each unit increase index in HI (significant at 99.9% level). The host institution also has little effect. The project's host institution index is measured by the total research dollars per full time faculty member. The share of GC contributions to each project will increase 0.007% for each additional index point (not significant). Projects with international co-funding receive approximately 0.21% (99% confidence level) higher funding than a project which has matching funds only from domestic sources, other things being equal. A proejct with an INTERGE^{3}LS is expected to have approximately 0.19% (95% confidence level) more funds than a project without a GE^{3}LS component. Moving on to the coefficient for the sector, a health project is expected to have approximately 0.26% (99.9% confidence level) more funding than a project in other sectors. For the region dummy, a project in Ontario is expected to receive 0.07% (not significant) more funding than projects not in Ontario, In short, there is no evidence of regional bias. A project not from Competitions I, II, II and ABC (i.e. directed funding) is expected to receive approximately 0.41% (99.9% confidence level) less funding than an open-competition project.

When only the open competitions were tested (Y_2 dependent variable) the competition dummy is not suitable to test in this section and was dropped. Table 6 shows the results of this regression.

Table 6: OLS estimation result for Y_2 (open-comp)			
Dependent Variable Y_2 (open-comp)			
Independent Variable	**Model A**	**Model B**	**Model C**
Intercept	0.57**	0.52**	0.65***
Leadership indicators (PI-HI)	0.02*	0.02	0.02*
Research intensity of host institution (Maclean's rank)	0.07	-0.00	-0.09
Partnership (International co-funding)	0.27*	0.21	0.20
INTERGE^{3}LS	0.26*	0.29**	0.28**
Dummy: Health		0.47***	0.48***
Dummy: Ontario			0.30*
Number of observation	94	94	94
F Statistics	3.27	5.65	5.47
Adjusted R^2	0.15	0.20	0.22
Significance levels (p value): * p<0.1; ** p<0.05; *** p<0.01			

Model C in table 6 delivered the highest R^2. The basic equation of this model is as follows:

$$Y = \underset{(2.74)***}{0.65} + \underset{(1.77)*}{0.02*(PI)} - \underset{(0.97)}{0.09*(Research)} + \underset{(1.44)}{0.2*(International)}$$

$$+ \underset{(2.10)**}{0.28*(INTERGE^3LS)} + \underset{(3.81)***}{0.48*(Sector\text{-}health)} + \underset{(1.92)*}{0.3*(Region\text{-}ON)}$$

The intercept term is equal to 0.65, which means the funding share of a project in the open pool of competitions (I, II, III, ABC) when the value of all other independent variables are equal to zero would be 0.65% (significant at 99% level). Leadership continues to matter. The

impact of a project's Principal Investigator (PI) translates to 0.02% more of the funding share of a project (90% confidence level) for each unit increase index in HI. International co-funding improves a project's budget share by 0.2% (not statistically significant) more than a project which is only supported from domestic sources. The host institution has little effect. On average, the GC contribution to each project in the open competitions increases by 0.09% for each additional institutional index point (not significant). An INTERGE^{3}LS project is expected to receive 0.28% (95% confidence level) more funding than a project with no GE^{3}LS component. A health project is expected to have approximately 0.48% (99.9% confidence level) more funding than a project in other sectors. On average, each Genome Ontario project is expected to have a 0.3% (90% confidence level) higher share of GC funding in the open competitions than a project from the other regions. This result, compared to that for the total of GC-funded projects, suggests that the peer reviewers appear to be more influenced by the location of the project than GC staff. Model C contains the regional dummies and the sector dummies. The adj-R^2 reaches a peak at 22%; more specified models with other contextual variables were tested but they offer little additional explanatory power (based on the static adjusted R^2).

Overall, this model suggests the processes in Competitions I, II, III and ABC delivered a weaker fit with the strategic of objectives of GC than the processes used by GC staff to develop the directed projects. This may be an artifact of the lessons learned from the earlier open competitions that were applied to the directed investments. However, there is some possibility that there may have been cognitive biases operating in the open competitions, as the dummy for the Ontario region is positive and significant at 90% level, which should not be observed in a competition where research excellence is the goal rather than allocations based on past capacity.

Conclusion and Policy Implications

This study has added to the policy evaluation literature, offering specific insights into an evaluation of Genome Canada. The analysis revealed that the overall fit for the entire investment program between 2001 and 2011 was about 34%, which is quite strong. We found the most important variables affecting resource allocation were the sector, presence of internaitonal parners, integrated GE3LS and the quality of the principal investigator. Other stated objectives of GC were either less important or insignificant. By segmenting the analysis into the open competition investments alone, we discovered the fit deteriorated (R^2 dropped from 34% to 22%), which suggests the directed investments are a stronger fit with the organizational goals. While the cause could not be conclusively determined, it might be attributed to (1) weaknesses in the peer-review processes involving a large number of competitive projects, (2) greater competence in adjudication as the directed investments mostly followed the four open competitions, or (3) effective and strategic effort by GC staff. Further analysis would be needed to determine this.

The results of our study show that about up to 35% of the variance in funding by project can be explained by the specific objectives of GC. The fit for the open competitions was not as strong as for the entire portfolio. By inference, this means that the allocations directed by GC staff (i.e. not engaged in open competition) were generally more strategic (this study cannot confirm that their outputs and outcomes were any different—that would be a different type of analysis). This may be surprising to many, as there is a general view that bureaucrats are more susceptible to political interference than arms-length openly competitive processes. One of two factors could be contributing to this divergence. It is possible that the competitive process

triggers cognitive gaps and biases among the peer-reviewers. There is some theory and evidence that peer review systems that are directed to assess multiple projects over a diverse set of variables will revert to system 1 decision-making, in other words fast and intuitive thinking that would lead to anchoring on a few operative factors and satisficing activity (Kahneman 2002; Simon 1956). Whether that theory applies here would have to be examined experimentally. The importance of sector and region for peer reviewers is significant. It may be that the staff of GC and the regional genome centres are susceptible to incentives as many might hypothesize, but that their incentives drive them to proactively backfill and compensate for any gaps in the open competition results. It would be necessary to look at the incentive and operational mandates of the GC staff to determine what drives these behaviors.

This study was limted to using publicly available data. Access to internal GC data—including the detailed proposals for the projects—would enable the model to be calibrated more precisely and would determine if there are any learning by doing effects as the organization has matured. We also lacked counterfactuals. The share of allocations was used as an in-sample differentiator. In a perfect world there would be full access to the structure and details of those proposals that failed to advance from LOI to full proposal and were not funded. That would provide an all-in analysis of the efficacy and fit of the GC decision system relative to its stated goals.

This study raises two interesting possibilities for further work. With access to more detailed data on both successful and unsuccessful projects, it should be possible to more effectively refine the model and isolate the effect of key variables in decision-making. This then could be used to assess the effect of framing and choice architecture in research decision-making. As noted above, this analysis tends to provide empirical evidence in support of the possibility that peer-evaluation systems are cognitively limited in the context of open competitions. Experimental work specifically related to the choices facing the peer-reviewers in GC could help more effectively develop appropriate choice architecture.

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