Research Evaluation, 28(2), 2019, 109–122
doi: 10.1093/reseval/rvy034
Advance Access Publication Date: 30 November 2018
Article

Government programs for university–industry partnerships: Logics, design, and implications for academic science

Emina Veletanlić* and Creso Sá

Centre for the Study of Canadian and International Higher Education, Ontario Institute for Studies in Education University of Toronto, 252 Bloor Street West, Toronto M5S 1V6, Canada

*Corresponding author. Email: emina.veletanlic@utoronto.ca

Abstract

Canada's research policy over the past three decades has steered national science toward industrial innovation. Yet, the outcomes of this policy orientation are debatable. Macro-level indicators continue to show weak performance in firm innovation, and there is also evidence that this policy stance has had material effects on science at the meso and micro levels. If so much public investment has gone into harnessing university–industry collaborations for a substantial period of time, why has Canada not seen an uptick in innovative activity? To address this puzzle, we turned our gaze to the policy machinery that promotes academic–industrial collaboration. We carried out case studies of two long-standing federal programs supporting research and development activities between universities and industry. Both programs are administered by the Natural Sciences and Engineering Research Council of Canada (NSERC), Canada's largest funder of natural sciences and engineering research. Drawing from multiple sources of data, we find that underneath the apparently successful implementation of these programs lies a misalignment between micro- and meso-level incentives for collaboration, and macro-level policy goals related to technological innovation and economic renewal. Our article makes two main contributions. First, it calls into question the escalating federal investments in university–industry partnership programs, as long as their ability to meet operational milestones remains the main source of evaluation. Second, it demonstrates the relevance and need for the literature to go beyond a focus on narrow technical questions at the micro level, and address broader questions about the purpose, goals, and beneficiaries of university–industry collaboration policy.

Key words: university–industry partnerships; research policy; technology transfer; innovation; Canada.

1. Introduction

Canadian research policy has since the 1980s been reoriented towards promoting university–industry partnerships, with the goal of stimulating technological innovation. The 1980s and 1990s were a particularly pivotal time for policy making: the federal government increasingly stressed the importance of research and development (R&D) for Canada's industrial base and productivity and also put forward new funding schemes to increase the number of university–industry partnerships and private-sector investments in R&D (e.g. Fisher et al. 2001; Atkinson-Grosjean 2006). Some scholars have argued that such measures showed 'the government's intention to tie future growth in research funding to private sector involvement' (Fisher et al. 2006: 79).

Currently, the federal research councils harbor multiple programs for R&D partnerships. The Natural Sciences and Engineering Research Council of Canada (NSERC) is the country's largest funder of natural sciences and engineering research and has promoted university–industry collaborations since its inception in 1976 through grants (Doern et al. 2016). Such grants have supported projects ranging significantly in scope and budget, from one researcher working with one company to large networks spanning academics and firms across Canada (Sá and Litwin 2011). The proliferation of these programs signaled a repositioning of academic science around an innovation agenda (Fisher and Rubenson 2010; Doern et al. 2016). Yet, the macro-level outcomes of this long-term policy orientation are far from clear. Canada remains a relative underperformer in industrial innovation, and some indicators show a deterioration of the country's standing in this area in recent years (Council of Canadian Academies 2018).

Nonetheless, this policy stance has had material effects on academic science at the meso and micro levels. Superimposing short-term innovation objectives onto research has entailed trade-offs within funding agencies between research fields and types of scientific activity. However, the budgetary allocations of research councils have a direct impact on academic science: what research gets funded, how investigators design projects, and who they partner with depends on the incentives available. An assessment of fundamental research supports in Canada has recently identified an erosion in field-initiated research over the past decade, which resulted from policy choices about the science budget and its distribution across the federal portfolio of science funding programs (Advisory Panel for the Review of Federal Support for Fundamental Science 2017).

The literature on the subject tends to investigate how public policy changes the dynamics and outcomes of university–industry collaborations. Questions usually asked concern whether government programs succeed in increasing interactions between universities and firms, whether companies that engage with universities are more innovative, and whether and how industry engagement changes the character of academic science (Poyago-Theotoky et al. 2002; Perkmann and Walsh 2009; Bruneel et al. 2010; Perkmann et al. 2013). Our study takes a step back and considers how specific programs inducing university–industry partnerships articulate certain logics concerning the drivers and outcomes of such linkages. These logics are also articulated in relation to broader macro-level policy objectives, which need to be considered in accounts of what these policy instruments accomplish.

It is against the background of the persisting puzzle of Canadian underperformance in innovation and the ongoing policy objective to address it through closer university–industry partnerships that we carried out a study of the Strategic Partnership Grants for Projects (SPG)[1] and the Collaborative Research and Development (CRD) programs. These programs are important for multiple reasons. With roots in the critical policy years of the 1980s, they are two of NSERC's oldest initiatives for university–industry collaborations. The expansion of such targeted funding schemes has been a focus for NSERC: the CRD program, in particular, has been referred to as 'one of the "centerpieces" or "pillars" of NSERC's strategy to build university-industry partnerships for innovation' (Science-Metrix 2010: 9).

What are the logics guiding the design and implementation of these programs? How do they facilitate university–industry partnerships? Who are their main users? Our case studies of the CRD and SPG programs addressed these questions at the meso and micro levels through an analysis of program documentation, funded project data, and interviews with principal investigators (PIs) of funded projects. Our analysis reveals a significant policy misalignment at two levels. First, at the micro level, the incentives these programs create for firms and universities to collaborate are not tightly coupled to broader policy objectives. Second, at the meso level, there is a critical misalignment between the overarching aims of developing new innovative firms and the reality that large incumbent firms in traditional economic sectors prevail as users.

This policy misalignment has important implications for Canada and other countries adopting similar programs. In Canada, we argue that collaboration programs such as the ones investigated in this article create transaction costs for scientific activity, but without meaningfully addressing their innovation objectives. More generally, the policy misalignment identified here is likely not unique to these Canadian programs. As other countries have sought to harness science for industrial innovation, instruments for university–industry collaboration have become more common. While a voluminous literature dealing with such initiatives exists, it tends to emphasize the assessment of program outcomes without questioning them, or yet critically examining the ideas guiding them.

2. Literature review

With the emergence of policy instruments to incentivize collaborations between academics and firms, scholars have explored various factors that contribute to positive outcomes. Government support for R&D is typically justified from an economic perspective: subsidies address market failures that lead to persistent private underinvestment in R&D (Hall and Lerner 2009). Through this lens, increases in private R&D effort and outputs are optimal outcomes, and studies on the economics of R&D investigate these effects at the national or regional level (Czarnitzki et al. 2007; Zúñiga-Vicente et al. 2014). Studies at the firm level ask different questions, seeking to explain the relationship between government subsidies and corporate decisions on R&D and whether they complement or substitute private spending (David et al. 2000; Wallsten 2000; Zúñiga-Vicente et al. 2014; Engel et al. 2016).

However, despite the multiplication of instruments for university–industry collaboration, there is no systematic evidence available concerning their effectiveness, both in Canada and beyond: '[w]hile some policy instruments have been extensively studied, other more traditional ones instead seem to be taken for granted... or at least are not subject to rigorous study' (Martin 2016: 164). The notion of success also depends to a great extent on what is being measured (Perkmann et al. 2011). In many cases, success has been attributed to a blend of 'soft' factors, including alignment of objectives, mutual trust, and how the project is managed (Barnes et al. 2002; Bruneel et al. 2010). On the flipside, that means that bureaucracy, inflexibility, and lack of understanding about culture and norms in academia and industry pose barriers to effective work (Siegel et al. 2003). Because evaluations typically concentrate on program management issues rather than the causality of the intervention and intricacies of the partnership, '[i]t is only possible to generate a set of general lessons for the design and implementation of collaborative support instruments' (Cunningham and Gök 2012: 39).

Generally, the thrust of government programs to stimulate university–industry partnerships is to increase their numbers. In fact, the mere existence of such initiatives is taken as evidence of stronger ties between the sectors in much of the literature. However, scholars caution that the assumption that 'more is better' might be misplaced, as differentiating the conditions under which partnerships generate both academic and industrial benefits is critical to minimize failure (Perkmann et al. 2013). The diversity of university–industry ties and their objectives requires policy makers to consider different strategies (D'Este and Perkmann 2011). These engagements are steeped in nuance, but understanding their subtleties may lead to a more effective balance between academic and commercial interests.

While there is general agreement that public subsidies for collaborative R&D are worth pursuing, relatively little work scrutinizes the logics behind these programs: What causal relationships are assumed to exist between the program and desired outcomes? How are those relationships reflected in program design and implementation? As Martin (2016) points out, effective policies bring about some change in the actors, their behavior, and their interactions among themselves and with their wider environment. Implicitly or explicitly, some 'theory' of who the actors are, how they behave, and how they will respond to incentives created by policy should inform program design. To address this gap, we employ an ideational approach to policy analysis to frame our study.

3. Conceptual approach

Generally defined, ideas are causal 'beliefs held by individuals or adopted by institutions that influence their attitudes and actions' (Emmerij et al. 2005: 214). Different types of ideas shape public policy, from broader 'worldviews', 'paradigms', and 'norms' that influence what is seen as legitimate and appropriate, to more specific 'frames' employed to make policies politically acceptable, and 'programmatic ideas' offering guidelines for solving a problem in ways that were considered successful in the past (Hall 1993; Stone 1996; Campbell 2002). Such paradigms and worldviews can limit alternative strategies to policy making because the cause-and-effect relationships are deemed tested and irrefutable, even in the face of competing evidence (Campbell 2002: 22–3).

We draw on the concept of *programmatic ideas* to tease out the actual content of instruments for university–industry collaborations. For policy makers, such ideas provide a familiar framework for how future programs should be implemented, with a 'taken-for-granted' causality from intervention to outcome. Seen through this lens, CRD and SPG programs embed causal theories that explain how their activities will lead to intended outcomes.

To better understand their logics, we distilled NSERC's existing and nearly identical CRD and SPG logic models (Science-Metrix 2010; R. A. Malatest and Associates Ltd. 2012) into a framework that fleshes out the programmatic ideas (Figure 1). The frameworks include action and change models, such as those used in the program evaluation literature (as per framework by Chen 2015), that illustrate the causal chains between the policy tool and final outcomes.

From the perspective of the research council, the success of these programs involves aligning incentives among universities, industry, and government partners. At the micro level, the models assume that the key incentive for *academic researchers* is new knowledge and technologies that can be shared with partners and the scientific community. Grants are expected to foster enduring linkages with firms that contribute positively to research, teaching, and institutional reputation. *For industry*, the key incentive is the reduction of the financial risk of R&D. The incentive for *government partners* is to gain knowledge that strengthens evidence-based decision-making. For participating *graduate students, post-doctoral fellows, and research staff*, incentives include gaining technical skills that will position them well for future employment.

At the meso level, the participation of different segments of firms and researchers in these programs relates to a number of environmental factors influencing universities and industry, including the state of the funding environment, market conditions, and firm strategies. For example, firms are subject to competitive pressures ranging from rapid changes in the technological landscape to fluctuations in product demand. Firm strategies are formulated accordingly to reflect priorities and the best 'defence' going forward, which may influence their participation in collaborative R&D (Porter 1979).

At the macro level, the university–industry programs operate within a greater innovation ecosystem. The *ecological context* depicted in Figure 1 highlights the wider trends shaping the programs and their outcomes. In the aggregate, these programs are construed as tools to address the 'commercialization gap' and help bolster the innovation performance of domestic firms. This 'commercialization gap' has constituted an important piece of the larger narrative on Canada's national economic performance for more than 30 years: it describes the inability of Canadian firms to commercialize the results of research and cross the chasm between the laboratory and commercial markets (Expert Panel on Business Innovation 2009; Science, Technology and Innovation Council [STIC] 2015).

4. Methodology

4.1 The cases

We identified two 'critical' cases for this study (Patton 2001), which were likely to provide rich information about the logics behind federal supports for university–industry collaboration. The SPG and the CRD programs are two of NSERC's oldest initiatives for university–industry activities and were adopted from the National Research Council (NRC) in 1978 and 1983, respectively (R. A. Malatest and Associates Ltd. 2012; NSERC 2016). The SPG program has since supported research areas considered vital to the national interest (Wilks 2004: 22), and the CRD program was established as a significantly enlarged legacy initiative from the NRC, with matching funds from industry as a new criterion for participation (NSERC 2016). Our two cases are established funding schemes with substantial growth over the years. Figure 2 shows the annual funding since 1991, the earliest year for which public data are available. The allocation to the programs nearly doubled from C$67 million in 1991–2 to C$119 million in 2015–16 (NSERC 2017a). The funds paid out to CRD-supported projects have increased steadily, while disbursements for SPG projects have fluctuated, experiencing a sharp decline after 2010, thus putting the current annual allocations on par with the levels in the early 1990s.

The CRD and SPG programs share conceptual and design elements: in both cases, a small number of researchers work with their industrial or government counterparts to create new knowledge and technologies. Table 1 provides an overview of their key features.

4.2 Approach

Programs were analyzed using mixed methods drawing from several sources of data. To identify programmatic ideas, we drew on program documentation including logic models, annual reports, and evaluations commissioned by NSERC. To assess the impacts of the programs at the meso level, or the relevant research community, we examined data on funded projects, including program investments in terms of amounts spent and the nature of funded work since the early 1990s. We drew from NSERC's awards database, which contains a rich data set with a combined total of 23,146 entries for CRD and SPG grants, going back to the 1991 competition year. Each entry represents funds disbursed on a 1-year or multi-year grant, alongside basic information, including the PIs, organizational affiliations, amounts disbursed per year, partners' names, and brief project descriptions. We extracted the raw data and built a data set for analysis.[2,3] When used in comparisons, all funds were converted to constant 2015 Canadian dollars.

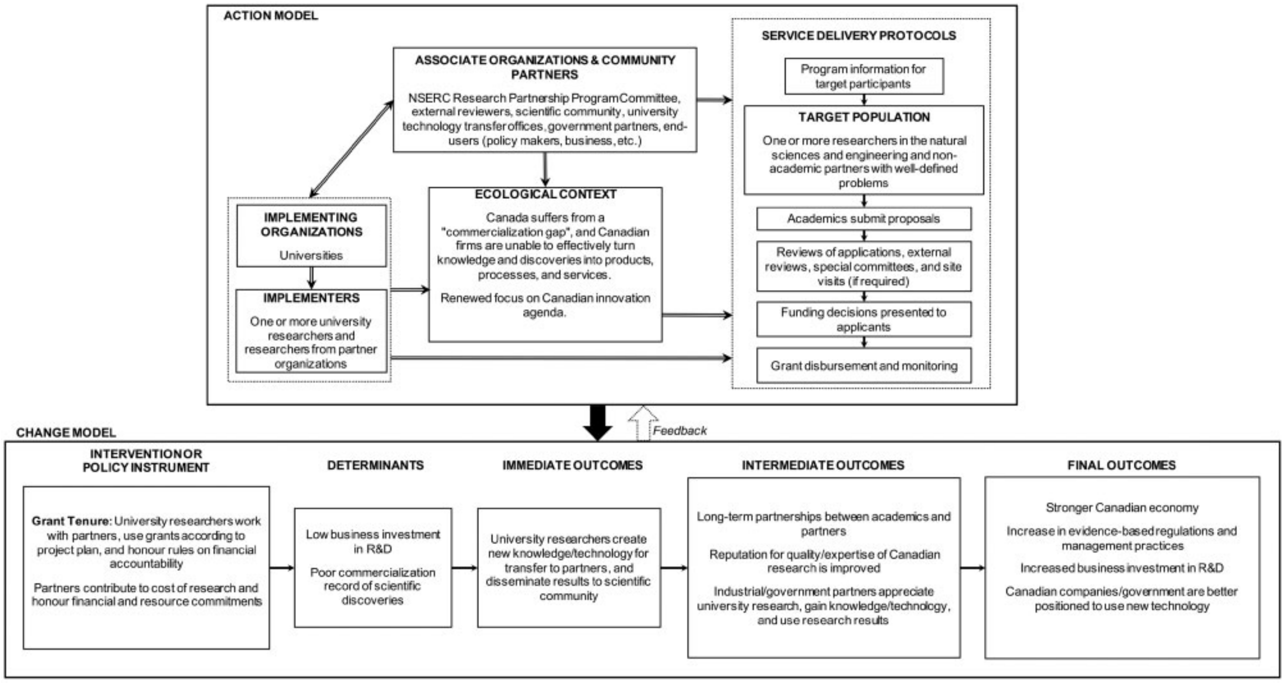

Figure 1. SPG and CRD program theory.
Note: Authors' adaptation from NSERC's program logic models (Science-Metrix 2010; R.A. Malatest and Associates Ltd. 2012).

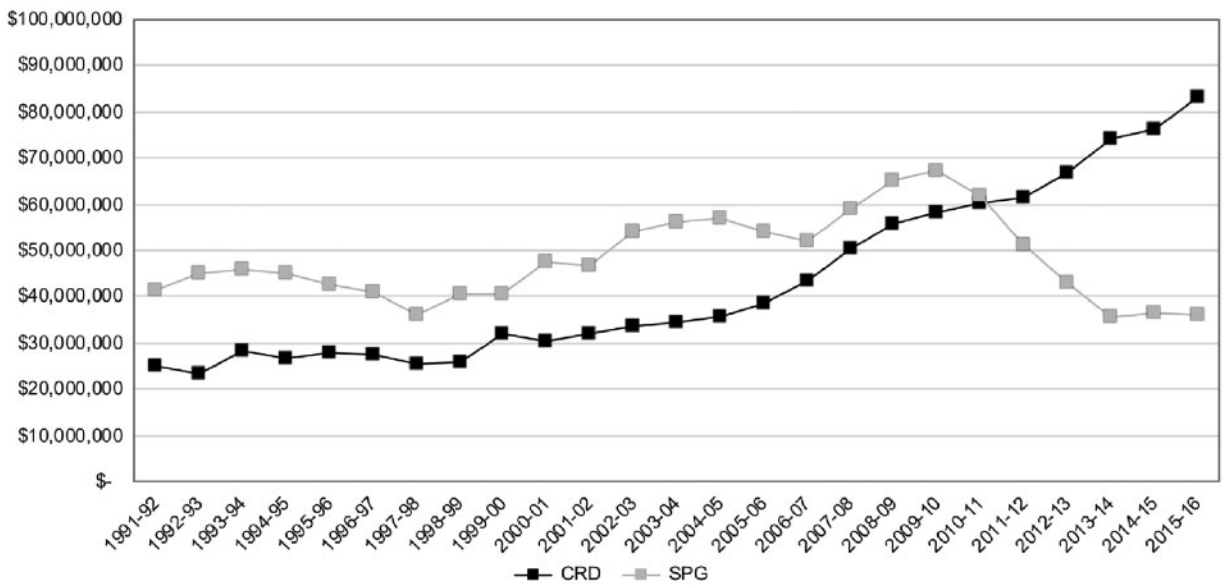

Figure 2. Total disbursements on active grants for CRD- and SPG-supported projects, in 2015 constant C$. (*Source:* NSERC's awards database.)
Note: Authors' calculations based on total amounts given out each year and the number of active grants.

To obtain a micro-level perspective of these programs, we examined the experiences of participants representing a sample of 27 funded projects (16 CRD and 11 SPG grants, reflecting the overall size and number of funded projects in each program). These were nested units of analysis within each case, which allowed a window into how the programmatic ideas relate to actual practice. Together, the projects reflect work conducted with small as well as large or multinational industrial partners operating, among others, in telecommunications, agri-food, forestry, and automotive and electronics manufacturing. To understand the origins and development of these projects, we interviewed both academic researchers and industrial partners. Nine academic researchers were interviewed from four universities across Canada, representing a range of disciplines—including physics, chemistry, biology, materials science, and engineering—and varied levels of experience with the programs. There was a balance in seniority and experience with the programs

Table 1. Overview of NSERC's CRD and SPG university–industry partnership programs. Amounts in Canadian dollars (*Sources:* NSERC 2016, 2017a,b,c.)

	CRD	SPG
Rationale	Promote well-defined projects between university and non-academic researchers Improve application and dissemination of knowledge Enhance competitiveness, productivity, and job creation Help trainees/researchers gain technical skills needed by user organizations	
Project duration	1–5 years (average 2–3 years)	1–3 years
Grant amount (per year)	\$10,000–\$500,000	\$30,000–\$200,000
Average annual amount (2015–16)	\$85,322	\$162,508
Success rate (approximate)	80%	20%
Project types	Projects with short- to medium-term objectives	Early-stage research with benefits to Canada's economy, society and/or environment within 10 years
Matching funds requirements from industry	Cash/in-kind contributions $\geq$ NSERC amount Partner cash $\geq$50% of NSERC amount	In-kind contributions
Targeted areas	Not defined	Advanced manufacturing Environment and agriculture Information and communications technologies Natural resources and energy

among our interviewees: five were senior researchers and four were mid-career faculty, and they ranged from having participated in one to five CRD and/or SPG grants. The four industrial partners interviewed represented two small private firms and two public companies—all with science-based products and services, but serving different markets. Two businesses work in clean technologies, one firm operates in the agri-food sector, and the fourth firm works in advanced materials and manufacturing. All representatives had either direct experience with the programs or were knowledgeable about how their firms deliver NSERC projects.

All participants were interviewed for 30–60 min, during which they were asked questions about their experiences and impacts on R&D activities. The interviewees were asked to describe the motivations for the projects, the specific benefits accrued to the firm or the research group, how their relationship evolved afterward, and how their involvement influenced the direction of their R&D activities. In terms of benefits, we probed a range of outcomes, such as the creation of new knowledge and products, access to increased funding for research, or ideas for research and teaching. In terms of challenges, we inquired about potential issues, including intellectual property negotiations and the balancing between basic and applied research. The interviews were coded, and the themes related to our research questions were extracted and added to the quantitative data to ascertain how the logics driving the programs translate to practice.

5. Results

Our analysis points to misalignments at the micro and meso levels between the ideas driving the programs and the incentives at play for academic researchers and industry partners, which culminate in the displacement of macro-level policy goals. Below we examine our findings at each level of analysis.

5.1 Micro-level misalignments

Our project-level evidence indicates that firm and university participants see both benefits and constraints in collaborating that are generally consistent with the literature (Siegel et al. 2003). Benefits for industrial partners include: risk reduction in R&D; access to new knowledge and promising research contributing to new or improved prototypes, products, and processes; access to expertise, techniques, and equipment; scientific credibility; and recruitment of talent (see Supplementary Table S1). The programs allow smaller firms to access research that helps elucidate the fundamental aspects of their product or process. Without these schemes, acquiring the expertise and equipment that come with the university partners would be difficult and cost prohibitive. Academic researchers also recognize that benefits are generated in these programs, including new publication streams, intellectual property in the form of invention disclosures and patents, financial support for further research and trainees, exposure of trainees to industry, and positive impact on teaching (see Supplementary Table S2).

Nonetheless, despite these perceived benefits, the nature of the Canadian industry determines the potential for partnerships. The programmatic ideas guiding CRD and SPG programs do not reflect the reality of Canadian firms' limited engagement in R&D, and program requirements actually create constraints for both firms and universities. While several researchers recognized the broadening of their research scope and new ideas arising from partner-driven projects as positive outcomes, some also acknowledged that the system would have the potential to generate better results if the program design matched the realities of partner firms. Low awareness among partners about program requirements and financial matching conditions also serve as barriers to participation (Table 2). In terms of creating enduring partnerships (as predicted by program theory in Figure 1), participants report mixed outcomes. While some relations endure, others are relegated to the background depending on priorities of participants. Usual frictions also appear around intellectual property negotiations and the traditional tensions between fundamental research (e.g. dissemination of results through literature) and applied work (e.g. secrecy and suppression of results to maintain a competitive advantage).

These difficulties influence how projects are designed and carried out. Participants express skepticism about not only the outcomes

Table 2. Micro-level misalignments

Misalignments	Sample quotations from interviewees
Expectation of industry engagement vs. variations in awareness about programs and their requirements	I'd say it's very hard [finding partners]... It's not like you can't find them. But it's not trivial. (academic researcher) [O]ne of our... biggest challenges [is] to identify industry partners that would be interested in partnering with us in a way that sort of works with our research programs. (academic researcher) [T]he big companies are actually very aware. In fact, they have someone specialized who usually works on tapping into all these government programs. They really know how to work the system. (academic researcher) I have to provide a lot of education. I have to provide detailed program requirements and guide them in writing letters of support. (academic researcher)
Matching requirements as indication of commitment vs. disincentive for participation	CRD's fatal flaw is the fact that you need matching cash from industry[.] Requiring cash contributions to move forward with projects that require long-term is difficult because the time to go to a commercial application is typically 15 years. (academic researcher) [W]e had [an SPG], and we wanted to continue it with a CRD grant...but the company at that point became less interested because they would have to provide cash. (academic researcher)
Mixed outcomes on the quality of relationships	It varies. Some companies are actually interested and have ongoing relationships. (academic researcher) The relationship was not sustained. The company was lukewarm about the outcomes because it was something that they didn't pay for and that was tangential to their activities. (academic researcher)

from partnerships but also rationales for engaging in the work. Two faculty members in applied fields where partnerships with industry are usual questioned the 'genuineness' of SPG applications that demand the creation of sufficiently compelling 'stories' and the demonstration of 'direct involvement' of firms. This is especially the case when businesses are not obliged to put in cash contributions and thus may not have strong interest in the results. An individual in a leadership position at a firm remarked on the significance of the work in generating new knowledge about the underlying technology. But when asked about potential applications, the interviewee acknowledged:

> *[I]f it's really really applied, the companies will just do it themselves. [In] my view, the university shouldn't be in the business of doing things that are really applied... [B]ut what I view these programs as doing is bridging an industry need where they don't understand something that has impact on their research and development, product development, product performance...and the university that can help them understand that need.*

Hence, while grants are recognized as valuable financial incentives for collaboration, major and minor obstacles to collaborative work remain in the design and execution of the projects.

5.2 Meso-level misalignments

Additional misalignments at the meso level further shape the effectiveness of these programs. The first misalignment identified in our analysis relates to the broader funding environment, which appears to be a major incentive for researchers' participation in university–industry programs. The second relates to the intended vs. actual private-sector participants: large firms are overrepresented in a large number of projects, potentially crowding out smaller entrants. Each misalignment is described in more detail below.

5.2.1 State of the funding environment

Our analysis shows that the SPG and CRD programs have mobilized a large number of academic researchers, supporting a total of 4,482 PIs over 25 years (Figure 3).[4] The CRD program, in particular, has continued to engage more and more researchers whose numbers have gone up in tandem with the steady increase in program funding (shown in Figure 2).

However, these programs do not operate in a vacuum; their relative attractiveness to scientists is related to the broader funding portfolio of the research councils. An important driver for researchers' engagement in these programs is the erosion of NSERC's budget for fundamental work (Advisory Panel for the Review of Federal Support for Fundamental Science 2017). NSERC's Discovery Grants are the premier source of funds for basic research in the natural sciences and engineering; they provide operating funding for faculty to support their laboratories and trainees. Figure 4 illustrates the disparity in the amounts disbursed through NSERC's various grants since the turn of the century. The average annual Discovery grant paid out to active researchers has been on a downward trend for 25 years, to the point where the mean annual installment to grantees in the 2015–16 fiscal year (C$33,359) is well under the going rate for one postdoctoral stipend (C$44,000) (Mitchell et al. 2013: 20). Put simply, Discovery Grant holders usually need to find supplementary sources of funding to support operations.

These trends were front and center in the decision-making process of the investigators interviewed for this study (refer to Table 3). The academics highlighted the ability to attract and retain trainees as an important benefit. Figure 4 suggests that, for some professors, CRD and SPG grants can provide two to five times more support per year than the basic Discovery Grant. Since CRD and SPG have not been supported with additional budgetary allocations, they have in effect steadily squeezed support for fundamental science within the research council. This has created a dependence among researchers on grants directed by industry-driven problems to supplement their lab operations. Indeed, some researchers frequently re-apply to these programs for additional support. A scan of the database shows that over the past 25 years, 29% of participating PIs have received funds for 5 or more years through these programs, potentially offering sizeable supplements to baseline funding and influencing how academic scientists frame their research agendas.

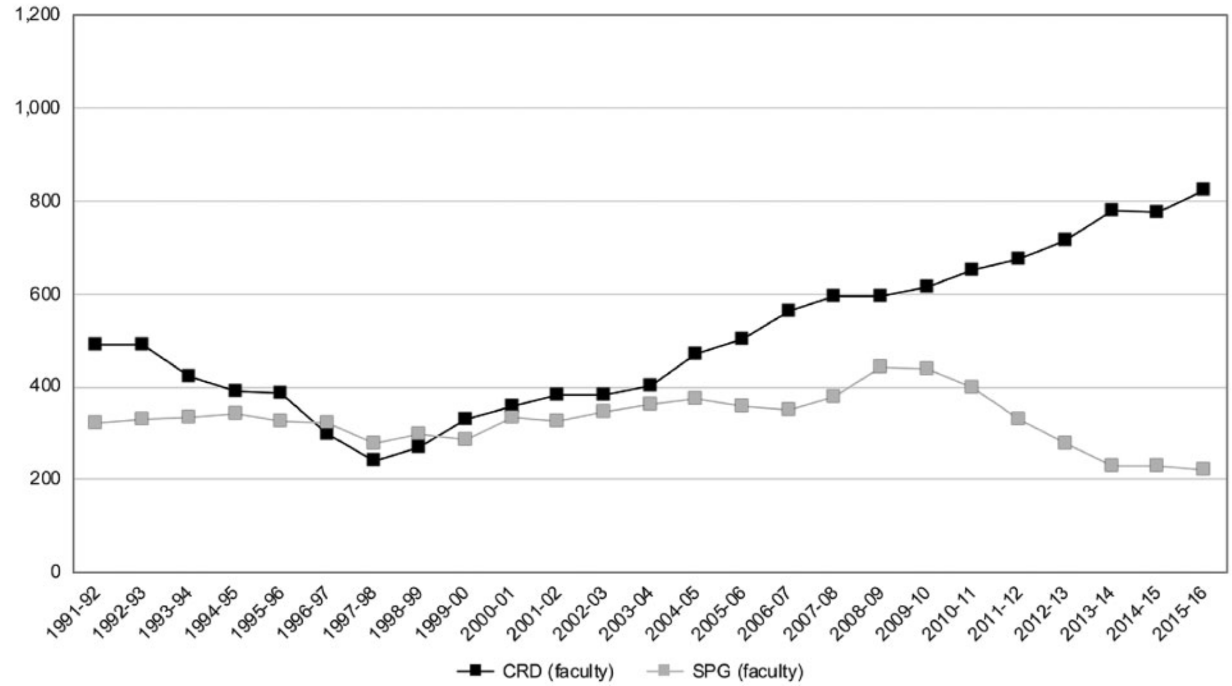

Figure 3. Number of academic project leads listed on active grants annually. (*Source:* NSERC's awards database.)
Note: Authors' calculations based on total amounts given out each year and the number of active grants.

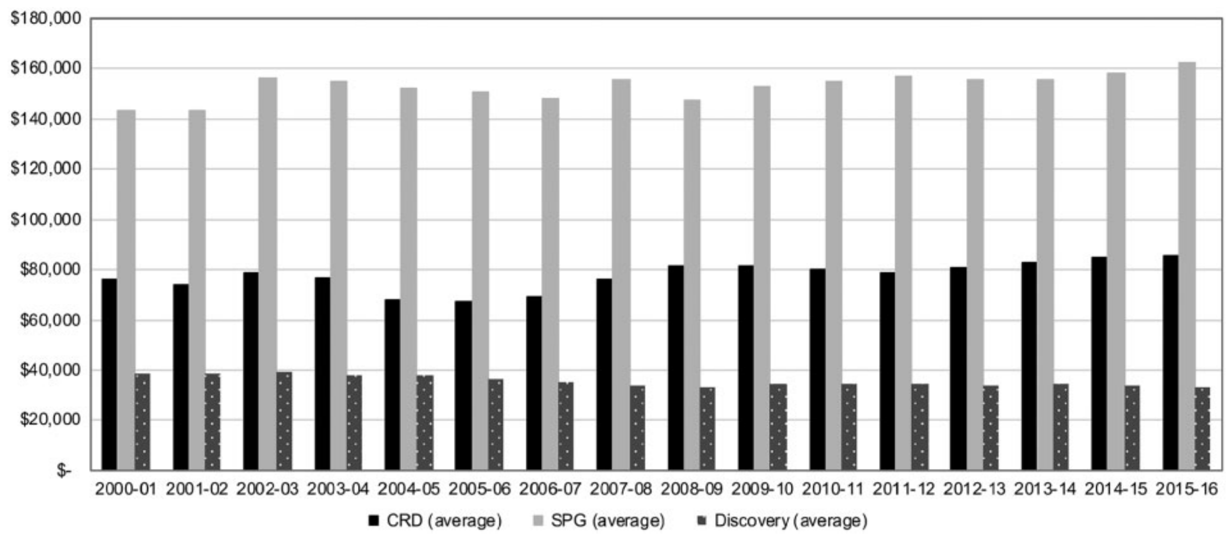

Figure 4. Average installments given out to active holders of CRD, SPG, and Discovery grants, in 2015 constant C$. (*Source:* NSERC's awards database.)
Note: Authors' calculations based on total amounts given out each year and the number of active grants.

The SPG stream, which doles out significantly larger support per researcher, funds narrow research questions in line with federal priority areas. Such programs have recently come under criticism from the research community because their increases have helped 'reduc[e] available support for independent, investigator-led research by front-line scientists and scholars'.[5] An engineering professor and past SPG grant holder remarked about the ethical dilemma that scientists face when applying for SPG grants—and increasingly other funding streams—that put the onus on researchers to work within the confines of a small number of fields. While academics strive for a balance between the fundamental and applied fronts, they recognize that their freedom to pursue research without a receptor has become severely limited. One electrical engineer well versed in these partnerships elaborated on the trade-offs generated by the current funding structure:

> *[It's] easy to see things that are present... But the things that we lost are harder to figure out... There's now heavy emphasis on doing innovation... It looks good for the government, for the university. But are we losing sight of some things that are more long-term, that, you know, don't have an immediate company receptor right away... I mean even the basic scientist hopes that*

Table 3. Challenges related to the funding environment and participation in university–industry programs

Challenge	Sample quotations from interviewees
Declining grants for fundamental research	[I]f you see a benefit, in general, for having a postdoc involved in your group, it's very hard to do [that] with a Discovery Grant… It's the thing that seeds everything. So, the challenge was that the seed money was very small, and it was disappearing for some people. But when you took that Discovery Grant envelope and split it up for all the researchers, the amount per researcher really hasn't changed, and everything else has. So, the buying power is very low. (academic researcher)
	There's no other really funding mechanisms in NSERC. The Discovery [Grant program] is too small. So, if you want to fund a project, then all of the projects need a partner from industry. (academic researcher)
Emphasis on thematic areas in university–industry programs	[It's] unprecedented in the world to pigeonhole researchers in this manner [in the SPG areas]. (academic researcher)
	Also, because the SPG has defined area of work… [S]ometimes they could be very limiting too… [S]ome areas get overemphasized and some really exciting areas are not part of this list. (academic researcher)
Re-directing of research	If the funding came with no strings attached, I would probably do things different. But simply, it forces your research into a certain direction… How my sort of career and research ha[ve] evolved over the past 25 years has been shaped quite heavily as to…where funding flows from. (academic researcher)
	Because of these grants and lack of other kinds of funding then, the research becomes more oriented to innovation-type projects… [T]he application on the commercialization could be five years, ten years from now… It's not immediate but it gears the research away from really fundamental topics. (academic researcher)
	When we set up a project with the university, we're designing and looking at problems that are important to us in a way that is important to us… I mean an ideal CRD is not independent. (firm representative)

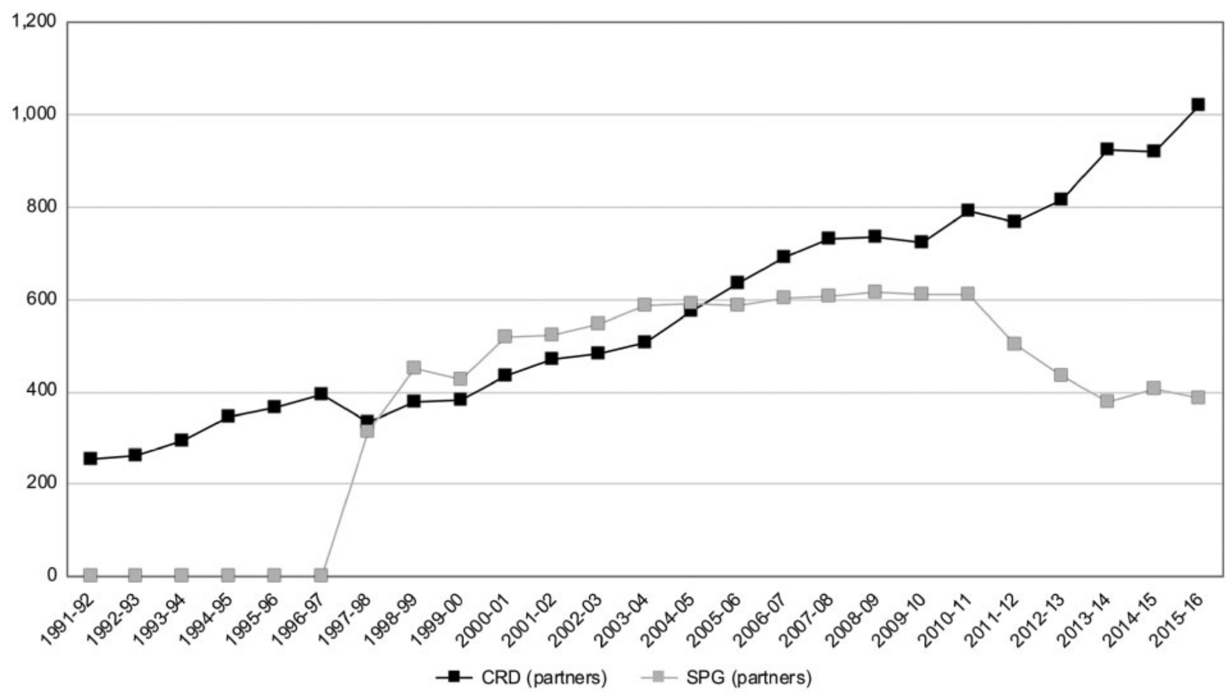

Figure 5. Number of partners listed on active projects every year. (*Source:* NSERC's awards database.)
Note: SPG projects had no partners listed on projects in the awards database prior to the 1996-97 fiscal year.

the knowledge will somehow impact society, but the mechanisms that are now in place to enable that might make it very difficult to do that kind of work.

5.2.2 Private-sector participants in university–industry partnerships: Who benefits from the programs?

NSERC promotes its research partnership programs as a way to 'boost private-sector R&D and commercialization'. Small- and medium-sized enterprises (SMEs) are expected to 'use partnerships to scale up', while larger firms are expected to 'access disruptive ideas necessary for new growth' (NSERC 2015). Over the past 25 years, nearly 3,300 organizations were listed as partners on CRD projects, and over 2,200 were involved as partners on SPG grants. Since academics must seek non-academic organizations to apply, the rise in partners is concomitant with the number of participating faculty and funding patterns (Figure 5).

With so many partners embedded in the system, the question is: Who are the main users of these programs? While over 97% of Canadian companies are small with fewer than 250 employees

Table 4. List of partners involved in the largest number of funded CRD projects

	Partner * = foreign subsidiary	Value of government funds in which partners were involved (constant 2015 C$)	Number of years listed as partner on projects	Number of academic leads involved
1	*Hydro-Québec*	*$55.4 M*	*25*	*126*
2	*Syncrude Canada*	*$34.2 M*	*24*	*80*
3	Bell Canada	$34.0 M	21	97
4	Consortium for Research and Innovation in Aerospace in Québec	$26.2 M	11	63
5	Bombardier	$24.5 M	22	71
6	General Motors Canada*	$23.8 M	23	71
7	*Shell Canada**	*$23.0 M*	*21*	*37*
8	*Teck Resources*	*$22.6 M*	*24*	*49*
9	*FPInnovations*	*$21.8 M*	*9*	*49*
10	Nortel Networks	$21.6 M	20	93
11	*Suncor Energy*	*$19.7 M*	*23*	*34*
12	*Xstrata**	*$18.0 M*	*25*	*47*
13	*Imperial Oil**	*$18.0 M*	*25*	*101*
14	Environment Canada	$17.9 M	23	107
15	*Resolute Forest Products**	*$14.7 M*	*18*	*24*
16	*Barrick Gold Corporation*	*$14.6 M*	*20*	*29*
17	IBM Canada*	$14.6 M	23	57
18	*Vale Inco**	*$14.0 M*	*8*	*44*
19	National Research Council	$13.7 M	21	35
20	*Husky Energy*	*$13.4 M*	*22*	*12*

Note: Firms operating in Canada's natural resources and energy sector are presented in italics.

Authors' calculations based on total amounts given out each year. Double counting of public funds may occur when multiple partners participate in projects. We have simplified our analysis by assuming that all subsidiaries and affiliates fall under the same parent companies regardless of when the subsidiary was acquired or the merger occurred. (*Source:* NSERC's awards database.)

(Organisation for Economic Co-operation and Development 2015), the data suggest that companies with the largest resources also effectively tap into more NSERC grants, potentially crowding out new entrants or at the expense of small, innovative firms the programs purport to support. Table 4 highlights organizations listed in multiple CRD projects that collectively have garnered the largest amounts of funding since 1991.[6]

Although Canada's policy discussions consistently emphasize the need to enhance the competitiveness of SMEs, and so do NSERC program materials, these data show a dichotomy between the smallest and largest companies. Clearly, investment in collaborative projects has overwhelmingly benefitted firms in Canada's traditional industries, including oil and gas, metals, minerals, energy, and forestry. Large incumbent firms in these sectors are overrepresented among program participants. In fact, 12 out of top 20 non-academic partners operate in natural resources and energy, a sector that has driven Canada's economic growth in recent decades. The remainder of the companies is other large Canadian firms or subsidiaries of well-established foreign companies.

An even higher degree of concentration of few large incumbent firms participating in these programs becomes evident when considering mergers, acquisitions and joint ventures. The firms in natural resources and energy sectors often engage in joint ventures to pool resources—and as our data demonstrate—to also tap into government funding. For example, multiple records show work involving some of the largest Canadian oil and gas companies. Syncrude Canada, ranked second on our list, is one of the largest Canadian oil sands operations (Syncrude Canada Ltd. 2017). It is a joint venture, with a majority share owned by Suncor Energy (ranked 11th among top CRD partners), and one-quarter controlled by Imperial Oil (ranked 13th on the CRD list).

Hence, corporate conglomerates boasting tremendous private assets continue to rally large numbers of researchers—despite the fact that these programs are intended to encourage the participation of high-technology SMEs. Larger firms are also more likely to participate multiple times in these programs. For instance, 3M Canada, Suncor Energy, General Motors of Canada, IBM Canada, and Syncrude Canada were all among the companies identified as partners in CRD projects for nearly every year over the 25-year span.[7]

What do these patterns mean? In some cases, what we see is the return of industrial partners and their sub-divisions to the program for concurrent or sequential work for a variety of projects. Interviewees pointed out that meso-level factors such as research orientation of firms, firm strategies, and market conditions may impact small and large firms differently with profound impact on project outcomes (Table 5).

One can argue that given the heft of the large or multinational firms in terms of their reach and resources, these projects can provide only incremental benefits for them. For example, C$1.8 million in government funds were injected into projects with Bombardier as a partner in the 2015–16 fiscal year. While funds do not flow directly to the company, Bombardier is expected to invest an equivalent contribution in these projects. But the equivalent investment represents only 0.08% of Bombardier's entire global R&D spending of C$2.3 billion in 2015 (Research Infosource 2016). Arguably, this is an insignificant fraction in the context of their worldwide operations.[8]

On the other hand, while one would expect these projects to constitute a more meaningful fraction in the context of R&D budgets of SMEs, some small firms are ambivalent about the 'materiality' of the grants to their business strategy. Interviewees commented on the

Table 5. Misalignments between programmatic ideas and the context of participating Canadian firms

Misalignment	Sample quotations from interviewees
Innovation orientation of Canadian industry limits domestic interest in R&D partnerships	The American companies are usually a lot better to work with...They are actually interested in the research... Canadian companies tend to, especially the large ones, tend to have more the attitude of: 'Well, do you have a final product for me?' (academic researcher) [W]e end up interacting with the R&D divisions, which might not actually be fully located in Canada. There might be people from the US, and...they pursue long-term research. But the Canadian bits tend to be much less research-oriented. (academic researcher)
Large firms over-represented in projects but less clear impacts	When we're working with this [large firm], I have no idea quite often what they do with that research... All their product development [is] closed. We would do one piece of development, we would give them results... We have no idea if they ever use it. (academic researcher) [These programs] make a significant difference to small companies, the kind that have the capacity to grow. [A large company] can grow from 100 to 105, but the growth from one employee to six employees is significant for small companies. (firm representative) But one of the big challenges that [small companies have] is that [they] don't have access to cash. (academic researcher)
Scope of projects funded vs. firm strategies and market conditions	All the commercialization would have happened through [the firm] and so, some of this was tied in with [their] overall plans... So, if [the business] wasn't going in that direction right away, then the resources for [the firm] are moved in other directions. (academic researcher) But because the work [in a CRD] tends to be fundamental... [T]he ultimate outcome is that it's going to increase our R&D productivity 20% in 5 years. That's really hard to justify spending a lot of time and energy...when you also have this other urgent near-term thing[.] (firm representative) [Our project with this particular university] was about to get converted into a CRD, but the business shifted, and there was no longer a need for the research. (firm representative)

shifting priorities of young high-tech firms that must remain agile in response to market trends. In some cases, by the time the projects come to a close after 2–3 years, the participating firm has already changed direction and may not have the capacity or the need to apply the project outcomes. Some researchers also remarked about the firms' 'lukewarm' reception to results, particularly in the case of SPG-supported work that does not require businesses to partially fund the research.

While the SPG program explicitly encourages government agencies as partners in an effort to strengthen evidence-based policy making, the extent to which public agencies partake in this program is surprising: we identified one-half of the 20 most active partners as other federal and provincial ministries or agencies (refer to Supplementary Table S3). Canada has a large 'intramural' system of research conducted across the various government agencies that is substantially larger than the government spending dedicated to 'extramural' research carried out in higher education. Our findings suggest that the SPG program has effectively been used as a vehicle for intra- and extramural collaborations for the past two decades.

5.3 Macro-level misalignment

The broader policy goals of the programs are articulated in terms of technological innovation and national firm competitiveness. However, the programs treat science and innovation as proximate activities, conceptually and practically, thus effectively operating with an incoherent theory of change. The programs re-purpose science funding mechanisms to assess innovation potential of the proposed projects, assuming that the usual procedures used for scientific research can reliably nurture innovation in aggregate. This is reflected in grant timelines, the nature of the work funded, and review processes. For example, the processing of grant applications may take up to 6–8 months for CRD and SPG programs, respectively. In the meantime, partners signed on to the project may evolve because they operate in a competitive marketplace where directions shift rapidly. In addition, one of the most important criteria for the adjudication of applications is 'scientific merit' (NSERC 2014). Since the programs emphasize 'originality and quality of research', it puts the onus on peer review to assess science through the lens of private-sector needs and make predictions on discoveries most suitable for translation into commercial breakthroughs. An electrical engineer spoke poignantly about the 'convoluted role' of the peer review in these programs:

> *[The peer review] speaks more about the individual and the topic but doesn't speak to the impact on the company. This is a disjointed process looking at a narrow segment of the whole process.*

Our review of project summaries available in the CRD and SPG database revealed a prevalence of collaborations that are more fundamental in nature, which is corroborated by statements from interviewees on the type of work conducted (Table 6). Although these activities produce knowledge that is important in creating or improving new products, they do not address their putative commercialization objectives. Even when couched in the context of industrial problem solving, funded projects tend to look at narrow questions within the scope of a larger applied problem. The SPG program takes on work that is scientifically riskier, permitting the exploitation of results within a 10-year horizon. But even with more generous timelines, further development and investment would be needed. Hence, academics return to programs for ongoing funding for projects in a manner that mimics seeking funding for fundamental research.

6. Discussion

There are clear mismatches between the programmatic ideas guiding the design of the SPG and CRD programs and the underlying problem of industrial innovation in Canada. Hence, this affects who these programs serve, what R&D they support, and how these

Table 6. Amalgamation of science and innovation

Sample descriptions of the work carried out in funded projects
[It's] definitely more on the research side... But it's kind of like doing R&D with the company.... [If] you really wanna push a product to market and you're really building prototypes, there are actually loans [and other programs] to the company. (academic researcher)
[For CRD], [t]he science has to be there. Does that science have a timeframe for implementation, and is there potential for the company to move it to a Technology Readiness Level 3? [For SPG,] it doesn't have to be even Technology Readiness Level 1. (academic researcher)
[A]ll of these projects that I've worked on under these two programs, I would say it's five to ten years out... If successful, it will still take like several years of development at least to turn it into a product. (academic researcher)
I would say that [projects] flow from NSERC Discovery to SPG to CRD... So, those would still be fairly early [on the innovation spectrum]. (academic researcher)
Whatever is done through CRD is scientifically risky. When it gets closer commercially[,] further work is needed. (firm representative)

programs operate. Our findings call into question the wisdom of ongoing and growing investments in these programs within the portfolio of science funding agencies. Further, considering the global dissemination of policy prescriptions for university–industry partnerships, our findings are relevant to other countries like Canada that are relative underperformers in industrial innovation and seek to redress this situation through similar initiatives.

The Canadian experience shows that the outcomes of the federal repositioning of science policy since the 1980s have been unsatisfactory in commercializing the results of research that would strengthen Canada's global standing in innovation (STIC 2015). Lodged at the core of the country's research funding system, the CRD and SPG programs are inspired by the notion that narrowing the gap between academia and industry can reverse the underinvestment by firms in R&D. While the logics suggest that financial incentives will induce academic scientists to work with their industrial counterparts, our analysis highlighted misalignments between programmatic ideas and the problems these programs seek to address.

This disconnect is evident at the micro level, as a recurring issue among academics is finding partners willing to engage in R&D partnerships, and especially partners willing to invest financial assets in projects. Even when partners are found, cultural differences cited in other studies on university–industry partnerships are also experienced (Bjerregaard 2010; Bruneel et al. 2010). The appeal of these programs has been partly due to concurrent reductions in funding for basic research across Canada's main research agencies. Investigators view partnership programs in the context of a zero-sum game in the availability of research funding, and they rationalize research agendas around program requirements. They strive to balance partnership goals with their interest in fundamental questions, even in cases where industry-oriented grants exceed grants dedicated to basic research.

In addition, it is not clear that long-term program outcomes are systematically traced. Without mechanisms in place to track the use of research results over time, it is difficult to verify the lasting outcomes desired by the programs. In particular, how are long-range—rather than one-time—increases in business investment in R&D stimulated among a wide range of firms as a result of these policy instruments? Do they have an impact on Canada's lackluster track record in the commercialization of scientific discoveries? In fact, macro-level indicators have shown Canada's position in business expenditures on R&D largely unchanged over the past two decades. Thus, programs have continued to invest in an important, albeit small piece of the innovation continuum, while expecting Canadian industries to adopt the results and subsequently bear the risk of commercialization.

What differentiates these initiatives from business supports under the direct oversight of federal ministries is the extent to which they were embedded into the bureaucratic structure of one of Canada's largest science funding agencies whose primary function is the support of research (as per NSERC Act 1985). One-third of NSERC's total C$1.2 billion budget is currently allocated to innovation and partnership programs. The policy orientation advanced by these programs has thus implications for academic science. The growing exposure of academic research to industry is thought to shape research efforts, thus diminishing the impact of established scientific sources and influencing the direction of science in the long term (Hottenrott and Lawson 2014). Private-sector involvement generates a 'skewing problem', in which scientific ideas and strategies are influenced by the funding source. Considering these effects and the state of the funding environment more broadly, our study suggests a pattern of 'loose steering': the programs for university–industry collaboration redirect attention in the scientific community to applied problems, mainly by constraining choices over research support. NSERC's continued promotion of these funding streams over the past 30 years has normalized the rationale and mechanisms of these programs in the conduct of science. This has been accompanied by greater private-sector involvement on selection committees tasked with deliberating on research projects that merit public funds (Polster 1998). Such new 'rules' have legitimized factors such as economic impact, 'utility', and the quality of the partnership with industry alongside scientific excellence as criteria for assessment.

This 'loose steering' toward industrial relevance is also based on unrealistic assumptions about the links between academic science and innovation. The program design does not capture the gaps that exist between university research and innovation in industrial settings. These programs conflate these activities and underestimate the extent to which they are separate processes following different logics and incentives. The logics severely undervalue the complexity, time, know-how, and costs associated with the transfer, use, and adoption of those results by partners. Participating companies must therefore carefully consider impacts on profitability and growth, on customers, as well as the urgency assigned to the problem within their strategic priorities.

On the whole, these programs that aim at growing Canadian-based innovative companies have attracted large firms in traditional industrial sectors. Not only are large corporations overrepresented but also resource-intensive sectors and government agencies are overpopulated among the most active partners. This illustrates a dilemma that academic scientists face when engaging with industry: most Canadian R&D takes place in a relatively small number of large corporations with the expertise and capacity to interact with universities. As academic scientists lead these projects, they seek out partners with the resources to commit to collaborative R&D projects. 'Receptor capacity', or the ability to implement project results, is an important factor in evaluating both CRD and SPG applications. Arguably, 'brand recognition' and the presumed capacity expected from large firms along with the size of their commitments may hold sway in awarding projects, with unfamiliar or smaller firms without a track record within the research council system drawing more scrutiny during the review. While individually the decisions to pursue large corporations make sense, the aggregate effect of these choices is an overwhelming emphasis on large, incumbent firms in traditional industries or government agencies. They potentially monopolize public funds at the expense of innovative new companies, which are expected to contribute to the diversification of Canada's natural resource-dependent economy (Brookfield Institute for Innovation and Entrepreneurship 2016; Innovation, Science and Economic Development Canada 2016).

The concentration of public funding on projects linked to a small number of well-resourced firms whose commitments may be immaterial relative to their expenditures on R&D globally, prompts questions whether the awarding of these grants contributes to corporate rent-seeking behavior (Tullock 1967). Debatably, the most desirable goal behind these programs is to create social and economic benefits based on public investments in research, but given the paucity of data on long-term outcomes, we cannot gauge the private and public benefits derived from projects. It is also difficult to assess the 'opportunity costs' associated with the allocation of funds to projects promoted by incumbent firms rather than smaller new entrants (Tollison 2012).

7. Conclusion

This article argues that the specific programmatic ideas guiding policy enticing industry to work with universities need greater scrutiny. Such ideas have governed the design of a wide range of programs around the world to address private-sector underinvestments in R&D. However, the Canadian cases illustrate that it is not sufficient to question only the outputs of such initiatives. They also demonstrate that the fundamental ideas and design elements behind established and well-accepted forms of incentive programs encouraging industrial–academic work warrant more detailed analysis.

Our study of two critical partnership programs adds to the evidence that the positioning of university research as a foundation for innovation may have had unintended micro- and meso-level consequences on Canadian science, with uncertain outcomes for firms. At the micro level, participating researchers and firms encounter 'operational barriers'—ranging from intellectual property negotiations to well-known tensions between basic and applied research—that hamper project execution and potential outcomes. The main meso-level drivers related to the funding environment and firm strategies demonstrate the need to address broader questions about the actors' motivations and goals in collaborations. For instance, overall funding trends in Canada have incentivized researchers to seek support through university–industry programs, but such mandated steering certainly has implications on researchers' attitudes toward these projects. Our study further suggests the importance of contextualizing these collaborative projects within a firm's overall business strategy, which has a profound impact on the adoption of results. Mandating science funding agencies to nurture technological innovation is not exclusive to Canada, and some of the issues raised here are relevant in other countries. This includes a potentially fruitful line of assessment research that examines program design elements as variables shaping research and innovation outcomes, considering the diversity of relevant policies in place.

Notes

1. NSERC provides funding for two types of strategic grants: Strategic Partnership Grants for Projects (SPG-P) and the Strategic Partnership Grants for Networks (SPG-N). In this article, we use SPG as an abbreviation for SPG-P.
2. While NSERC also supports large-scale networks of researchers and organizations working in targeted areas through its SPG-N, our study focused on Strategic Partnership Grants for Projects that, like the CRD grants, typically involve a small number of researchers per project.
3. CRD-supported projects in our analysis include all grants labeled as 'Collaborative Research and Development Grants' and 'Collaborative Research and Development Grants—Government (H)' in NSERC's awards database.
4. The CRD and SPG programs have funded 3,549 and 1,791 PIs, respectively, with 858 PIs participating in both programs since 1991.
5. This criticism was captured in the nationwide review of federal government programs for science (Advisory Panel for the Review of Federal Support for Fundamental Science 2017: xi).
6. All research council funds flow to the academic researchers; no funds are permitted to be transferred from the university to the partners, but the partners are expected to benefit from the work conducted under the grants.
7. These firms also represent some of the largest R&D spenders in Canada. The Canadian industry invested C$15.5 billion on R&D in 2015, but C$12.8 billion (82.6%) were spent by a group of 100 companies (STIC 2015; Research Infosource 2016). Many such corporations are also represented on our list of most active partners, including Bombardier, IBM Canada, Suncor Energy, and Imperial Oil.
8. Similarly, that percentage is 1.5% for Suncor Energy (global spending was C$200 million in 2015) and 0.2% for Blackberry (global spending was nearly C$600 million in 2015).

Supplementary data

Supplementary data is available at *Research Evaluation Journal* online.

Acknowledgements

The authors would like to greatly acknowledge Dr James Li for his help in generating an awards data set amenable to analysis and Mr. Stuart Rolfe for his advice on approaches to analyze the resulting data. The authors would also like to express gratitude to two anonymous reviewers who provided helpful comments on drafts of this manuscript. An earlier version of this document was presented at the CHER 2017 conference in Jyväskylä, Finland on 28 August 2017.

Funding

This work did not receive financial support from funding bodies or other public, for-profit, or not-for-profit organizations.

References

Atkinson-Grosjean, J. (2006) *Public Science, Private Interests: Culture and Commerce in Canada's Networks of Centres of Excellence*. Toronto, ON: University of Toronto Press.

Advisory Panel for the Review of Federal Support for Fundamental Science (2017) *Canada's Fundamental Science Review*. <http://www.sciencereview.ca/eic/site/059.nsf/vwapj/ScienceReview_April2017-rv.pdf/$file/ScienceReview_April2017-rv.pdf> accessed 26 May 2017.

Barnes, T., Pashby, I., and Gibbons, A. (2002) 'Effective University–Industry Interaction: A Multi-Case Evaluation of Collaborative R&D Projects', *European Management Journal*, 20/3: 272–85.

Bjerregaard, T. (2010) 'Industry and Academia in Convergence: Micro-Institutional Dimension of R&D Collaboration', *Technovation*, 30/2: 100–8.

Brookfield Institute for Innovation (2016) *The State of Canada's Tech Sector, 2016*. <http://brookfieldinstitute.ca/research-analysis/the-state-of-canadas-tech-sector-2016/> accessed 7 Aug 2017.

Bruneel, J., D'Este, P., and Salter, A. (2010) 'Investigating the Factors That Diminish the Barriers to University-Industry Collaboration', *Research Policy*, 39/7: 858–68.

Campbell, J. L. (2002) 'Ideas, Politics, and Public Policy', *Annual Review of Sociology*, 28: 21–38.

David, P. A., Hall, B. H., and Toole, A. A. (2000) 'Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence', *Research Policy*, 29/4–5: 497–529.

D'Este, P., and Perkmann, M. (2011) 'Why Do Academics Engage with Industry? The Entrepreneurial University and Individual Motives', *Journal of Technology Transfer*, 36/3: 316–39.

Chen, H. T. (2015) *Practical Program Evaluation: Theory-Driven Evaluation and the Integrated Evaluation Perspective*. Thousand Oaks, CA: SAGE Publications, Inc.

Doern, G. B., Castle, D., and Phillips, P. W. (2016) *Canadian Science, Technology, and Innovation Policy: The Innovation Economy and Society Nexus*. Montréal, QC: McGill-Queen's University Press–MQUP.

Council of Canadian Academies (2018) *Competing in a Global Innovation Economy: The Current State of R&D in Canada', Expert Panel on the State of Science and Technology and Industrial Research and Development in Canada*. Ottawa, ON: Council of Canadian Academies.

Cunningham, P., and Gök, A. (2012) '*The Impact and Effectiveness of Policies to Support Collaboration for R&D and Innovation*', Nesta Working Paper No. 12/06. <https://www.nesta.org.uk/publications/impact-and-effectiveness-policies-support-collaboration-rd-and-innovation> accessed 9 Nov 2017.

Czarnitzki, D., Embersberger, B., and Fier, A. (2007) 'The Relationship between R&D Collaboration, Subsidies and R&D Performance: Empirical Evidence from Finland and Germany', *Journal of Applied Econometrics*, 22/7: 1347–66.

Emmerij, L., Jolly, R., and Weiss, T. G. (2005) 'Economic and Social Thinking at the UN in Historical Perspective', *Development and Change*, 36/2: 211–35.

Engel, D., Rothgang, M., and Eckl, V. (2016) 'Systemic Aspects of R&D Policy Subsidies for R&D Collaborations and Their Effects on Private R&D', *Industry and Innovation*, 23/2: 206–22.

Expert Panel on Business Innovation (2009) *Innovation and Business Strategy: Why Canada Falls Short*. Ottawa, ON: Council of Canadian Academies, <http://www.scienceadvice.ca/en/assessments/completed/innovation.aspx> accessed 1 June 2017.

Fisher, D. et al. (2006) *Canadian Federal Policy and Postsecondary Education*. Winnipeg, MB: Printcrafters.

Fisher, D., Atkinson-Grosjean, J., and House, D. (2001) 'Changes in Academy/Industry/State Relations in Canada: The Creation and Development of the Networks of Centres of Excellence', *Minerva*, 39/3: 299–325.

Fisher, D., and Rubenson, K. (2010) 'Canada', in Dill D. D. and Van Vught F. A. (eds.) *National Innovation and the Academic Research Enterprise: Public Policy in Global Perspective*, pp. 62–116. Baltimore, MD: Johns Hopkins University Press.

Hall, J. A. (1993) 'Ideas and the Social Sciences', in Goldstein J. and Keohane R. (eds.) *Ideas and Foreign Policy: Beliefs, Institutions and Political Change*, pp. 31–56. Ithaca, NY: Cornell University Press.

Hall, B. H., and Lerner, J. (2009) 'The Financing of R&D and Innovation', *National Bureau of Economic Research*', Working Paper 15325 <http://www.nber.org/papers/w15325> accessed 5 Nov 2017.

Hottenrott, H., and Lawson, C. (2014) 'Research Grants, Sources of Ideas and the Effects on Academic Research', *Economics of Innovation and New Technology*, 23/2: 109–33.

Innovation, Science and Economic Development Canada (2016) 'Innovation and Skills Plan,' in *Innovation for a Better Canada, What We Heard*. <https://www.ic.gc.ca/eic/site/062.nsf/vwapj/Innovation-for-a-better-Canada.pdf/$file/Innovation-for-a-better-Canada.pdf> accessed 7 Aug 2017.

Martin, B. R. (2016) 'R&D Policy Instruments–A Critical Review of What We Do and Don't Know', *Industry and Innovation*, 23/2: 157–76.

NSERC (2014) *Collaborative Research and Development Grants*. Instructions to Referees – Form 140. <http://www.nserc-crsng.gc.ca/OnlineServices-ServicesEnLigne/instructions/140/CRD_eng.asp> accessed 1 June 2017.

NSERC (2015) *NSERC Drives Innovation*. Innovation Factsheet. <http://www.nserc-crsng.gc.ca/_doc/Innovation-Factsheet-EN.pdf> accessed 1 June 2017.

NSERC (2016) *Chronicle of Past Events*. <http://www.nserc-crsng.gc.ca/NSERC-CRSNG/History-Historique/chronicle-chronique_eng.asp> accessed 1 June 2017.

NSERC (2017a) *Awards Database*. <http://www.nserc-crsng.gc.ca/ase-oro/index_eng.asp> accessed March 2017.

NSERC (2017b) *Collaborative Research and Development Grants* (*Including* DND/NSERC Research Partnerships). <http://www.nserc-crsng.gc.ca/Professors-Professeurs/RPP-PP/CRD-RDC_eng.asp> accessed 30 May 2017.

NSERC (2017c) *Strategic Partnership Grants*. <http://www.nserc-crsng.gc.ca/Professors-Professeurs/RPP-PP/SPG-SPS_eng.asp> accessed 30 May 2017.

NSERC Act (1985) *Functions and Powers, Sections 4–6*. <http://laws.justice.gc.ca/PDF/N-21.pdf> accessed 2 Feb 2018.

Organisation for Economic Co-operation and Development (2015) *Enterprises by Business Size*. <https://data.oecd.org/entrepreneur/enterprises-by-business-size.htm> accessed 29 Nov 2016.

Patton, M. Q. (2001) *Qualitative Research and Evaluation Methods*. Thousand Oaks, CA: SAGE Publications, Inc.

Perkmann, M., and Walsh, K. (2009) 'The Two Faces of Collaboration: Impacts of University-Industry Relations on Public Research', *Industrial and Corporate Change*, 18/6: 1033–65.

Perkmann, M., Neely, A., and Walsh, K. (2011) 'How Should Firms Evaluate Success in University-Industry Alliances? A Performance Measurement System', *R&D Management*, 41/2: 211–16.

Perkmann, M. et al. (2013) 'Academic Engagement and Commercialisation: A Review of the Literature on University-Industry Relations', *Research Policy*, 42/2: 423–42.

Polster, C. (1998) 'From Public Resource to Industry's Instrument: Reshaping the Production of Knowledge in Canada's Universities', *Canadian Journal of Communication*, 23/1: 91–106.

Porter, M. E. (1979) 'How Competitive Forces Shape Strategy', *Harvard Business Review*, 57/2: 137–45.

Poyago-Theotoky, J., Beath, J., and Siegel, D. S. (2002) 'Universities and Fundamental Research: Reflections on the Growth of University-Industry Partnerships', *Oxford Review of Economic Policy*, 18/1: 10–21.

R.A. Malatest and Associates Ltd. (2012) *Evaluation of the Strategic Project Grants (SPG) Program*. Summary Report. <http://www.nserc-crsng.gc.ca/_doc/Reports-Rapports/Evaluations/SPGReport2012_e.pdf> accessed 27 Feb 2017.

Research Infosource (2016) Canada's Top 100 Corporate R&D Spenders. <https://researchinfosource.com/top100_corp.php> accessed 21 Feb 2017.

Sá, C. M., and Litwin, J. (2011) 'University-Industry Research Collaborations in Canada: The Role of Federal', *Policy Instruments', Science and Public Policy*, 38/6: 425–35.

Siegel, D. S. et al. (2003) 'Commercial Knowledge Transfers from Universities to Firms: Improving the Effectiveness of University-Industry Collaboration', *Journal of High Technology Management Research*, 14/1: 111–33.

Science-Metrix (2010) *Evaluation of the Collaborative Research and Development Grants Program*. Final Evaluation Report. <http://www.nserc-crsng.gc.ca/_doc/Reports-Rapports/evaluations/CRD_Evaluation_Report_e.pdf> accessed 27 Feb 2017.

Science, Technology and Innovation Council (STIC) (2015) *State of the Nation 2014*. Canada's Science, Technology and Innovation System', in Canada's Innovation Challenges and Opportunities. <http://www.stic-csti.ca/eic/site/stic-csti.nsf/eng/Home> accessed 29 Nov 2016.

Stone, D. (1996) *Capturing the Political Imagination: Think Tanks and the Policy Process*. London: Frank Cass.

Syncrude Canada Ltd. (2017) *Ownership and Investors*. Syncrude Ownership. <http://www.syncrude.ca/our-company/ownership-and-investors/> accessed 7 June 2017.

Tollison, T. (2012) 'The Economic Theory of Rent Seeking', *Public Choice*, 152/1–2: 73–82.

Tullock, G. (1967) 'The Welfare Costs of Tariffs, Monopolies, and Theft', *Western Economic Journal*, 5/3: 224–32.

Mitchell, J. S. et al. (2013) 'The 2013 Canadian Postdoc Survey: Painting a Picture of Canadian Postdoctoral Scholars', in *The Canadian Association of Postdoctoral Scholars and Mitacs*. <https://www.mitacs.ca/sites/default/files/caps-mitacs_postdoc_report-full_oct22013-final.pdf> accessed 18 July 2017.

Wallsten, S. J. (2000) 'The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program', *The RAND Journal of Economics*, 31/1: 82–100.

Wilks, B. (2004) *Browsing Science Research at the Federal Level in Canada: History, Research Activities and Publications*. Toronto, ON: University of Toronto Press.

Zúñiga-Vicente, J. Á. et al. (2014) 'Assessing the Effect of Public Subsidies on Firm R&D Investment: A Survey', *Journal of Economic Survey*, 28/1: 36–67.