Science-Metrix

EVALUATION OF THE COLLABORATIVE RESEARCH AND DEVELOPMENT GRANTS PROGRAM

FINAL EVALUATION REPORT

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by

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submitted to

The Evaluation Steering Committee of the CRD Program

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EXECUTIVE SUMMARY

The Natural Sciences and Engineering Research Council of Canada (NSERC) mandated Science-Metrix to carry out the evaluation of its Collaborative Research and Development (CRD) program. This Evaluation Report presents the findings of this evaluation, which covers the 1997–2008 period. These findings indicate that the CRD program is relevant, well designed, appropriately delivered, and generally provides considerable long-term benefits to industrial partners, academic researchers and highly qualified personnel (HQP). The full list of key findings, which follows this Executive Summary, supports the conclusions and recommendations of this evaluation, which are summarized here.

The impacts observed for the three key beneficiary groups (industrial partners, academic researchers and HQP) are well aligned to the CRD program's expected outcomes. More specifically, the CRD program enables industrial partners to benefit from collaborative R&D with a university-based expert on well-defined projects within the context of a wide variety of different needs and corresponding project objectives. As well as acquiring new knowledge from the CRD research results, 80% of industrial partners have observed concrete impacts stemming from CRD projects. These impacts include new products and services, which often allowed for increased competitiveness, as well as new or improved processes, which often led to increased productivity. Furthermore, broader socio-economic impacts and organizational benefits, such as the enhancement of R&D activities, relationship-building and access to HQP, are crucial factors that both encourage the participation of industrial partners in CRD projects and add value to these grants. However—despite an appreciable reach of the program among Canadian firms and a growing number of firms participating in CRD projects—there remains room to increase awareness of and "buy-in" to the CRD program among the business sector.

> *"Our participation in this program was an invaluable experience that has shown us a level and type of research that we were previously unaware of.... [This research] is far more sophisticated and comprehensive then any other efforts we have previously sponsored [with smaller research companies]." – Industrial partner*

Academic researchers who participated in collaborative R&D with industrial partners achieved a wide range of objectives, not only because of the availability of CRD funds to conduct research but also because of the high level of involvement of industrial partners and the participation of students. They created new knowledge and technologies that were extensively disseminated to the industrial partners and the wider academic community. Knowledge transfer was achieved through the attainment of several hundred patents and the publication of several thousand papers. Academic researchers also report that the CRD program helped to enhance and shape their research programs, their reputation and their teaching. Yet opportunities for researchers to access and benefit from the program were sometimes limited by the cash

> *"This is NSERC's best grant program. It's the one that has contributed the most to the development of my research and to the training of graduate students. I think it's the program with the best cost-benefit ratio by far. The benefits are HQP, publications, impacts for industry and on fundamental research. The program is the envy of my colleagues in France, Belgium, Switzerland, the US, etc." – Academic researcher*

requirements for industrial partners (particularly for small and medium enterprises) and the workload and timeframe involved in the application process (especially for small/short-term CRD projects).

This evaluation is the first time that evidence relating to the impacts of the CRD program has been collected directly from HQP. The findings show that the participation of HQP in CRD projects is highly significant, both with regard to their contribution to the research and to the subsequent professional and financial benefits they report. An average of nine HQP participated in each CRD project, many for at least one calendar year. Through their interactions with industrial partners and their exposure to R&D in industrially-relevant environments, HQP acquired valuable skills and experience and generally needed less training once hired. Consequently, a large proportion has since found employment in their field—including 10% within the industrial partner's organization. HQP involvement in CRD projects also builds capacity for future collaborative R&D (in both the academic and private sectors) and contributes importantly to the program's overall economic impact through increased human capital.

> *"It is a great opportunity. An unbelievable one. You learn at such a rate and it is so broad that you just couldn't get this in a classroom. You couldn't get this in a company. You just couldn't. They are paying you to do this research and produce an academic paper and the industry gets the software, but what you get is crazy amounts of knowledge and skills." – HQP*

Considering this evidence, as well as the fact that all program stakeholders agree to the need for and relevance of the CRD program, the findings of this evaluation support the continuation of this program, as well as efforts to increase the breadth and reach of its impacts among key beneficiaries. Potential improvements to the CRD program mainly relate to ways in which the program's delivery could be more efficient and better meet outstanding needs, but the fundamental aspects of the program's design or delivery are not in question here. The Conclusions and Recommendations section (page 62) provides additional detail and justification for the following recommendations.

- **Recommendation 1**: Maintain the CRD program in its current form. Incremental improvements to program delivery should continue to be made in response to changes in the research landscape, in the needs of key beneficiaries, and in the number of applications and ongoing CRD grants.
- **Recommendation 2:** Increase the outreach and visibility of the CRD program—particularly among industry—to promote awareness about the design and benefits of the program among stakeholders and to increase industry "pull".
- **Recommendation 3:** Pursue plans to explore a Pre-Collaborative Research and Development (Pre-CRD) grant pilot program, with a reduced requirement for partner contributions and a streamlined application process.
- **Recommendation 4:** Maintain support for the participation of HQP—including students—in CRD projects. As part of Recommendation 2, communicate more prominently to program stakeholders both the contributions of HQP to CRD projects and the benefits of CRD participation for HQP.

LIST OF KEY FINDINGS

Finding 1: The objectives and outcomes of the CRD program are clearly consistent with both departmental and government strategic planning, whereas supported projects reflect current S&T priorities. 10
Finding 2: CRD program stakeholders see a strong continuing need for the program, and consider it an effective means to initiate and support university-industry collaborative R&D projects. 12
Finding 3: Academic researchers and industrial partners continue to rely (to a substantial extent) on the CRD program to support their collaborative R&D projects. The extensive reach of the program throughout Canadian industry and the restricted scope and impact of projects that did not receive CRD funding also suggest that it occupies an important niche among alternative sources of support in Canada. 14
Finding 4: The CRD program responds to a large proportion of the needs identified by industrial partners and academic researchers, although a small number of outstanding needs may still exist, both overall and for certain sub-groups of researchers and partners. 17
Finding 5: The existence of pre-established relationships between academic researchers and industrial partners (or "gateways" that help forge these relationships), combined with the flexibility built into the design and delivery of the CRD program, are key facilitating factors for program participation. 20
Finding 6: Factors that inhibit participation in the CRD program include the cash requirement for industrial partners, IP management issues (in spite of adjustments made to NSERC's IP policy), and the workload and timeframe involved in the application process for small/short-term CRD projects. 21
Finding 7: Industrial partners are deriving tangible benefits from the CRD program, even in cases where technical setbacks are encountered. 23
Finding 8: Based on their high levels of satisfaction with and continued participation in collaborative R&D projects with academia, industrial partners are realizing benefits from these collaborations. 24
Finding 9: CRD project research results are consistently and effectively transferred to industry partners, leading to an increased knowledge base among the vast majority of partner organizations (>90%). 26
Finding 10: Industrial partners use research results to improve and/or develop specific new products, services and processes in over one third of CRD projects. 27
Finding 11: The benefits of increased opportunities for networking and access to HQP through CRD projects provide significant value added for industrial partners; access to HPQ, in particular, can act as a driver of industry participation in the CRD program. 29
Finding 12: Impacts on competitiveness and productivity are perceived to occur in up to roughly 20% to 40% of CRD projects but are difficult to quantify. These impacts are more likely to be multiplied across several firms when the industrial partner(s) include industry associations or consortia. 31
Finding 13: Impacts of CRD grants on internal R&D are greater for SMEs than for large organizations. 32
Finding 14: The economic impact analysis of the CRD program indicates a positive return on investment on the Canadian GDP, particularly if the increased human capital resulting from the training of HQP is considered. 34
Finding 15: Academic researchers report that funding, partner involvement, and participation of HQP are key to the achievement of CRD project objectives. 39
Finding 16: Academic researchers created and widely disseminated new knowledge and technology, for an average of 18 publications (papers, conferences/posters and theses) per CRD project. At least 135 patents were issued as a result of the 460 CRD projects examined in the web survey. 42
Finding 17: The CRD program helped to shape and strengthen participating academic researchers' research and reputations and increased opportunities for researchers to obtain further research funds. 44
Finding 18: Academic researchers use the knowledge, tools and materials they acquired through the CRD project to enhance and inform their existing courses and, sometimes, to create new courses. 44
Finding 19: An average of nine HQP participate per CRD project, many for at least one calendar year—this provides significant opportunities for HQP to contribute to and benefit from the program. 46
Finding 20: HQP conducted research and acquired skills in an industrially-relevant environment, particularly those that had a high degree of interaction with industrial partners. 48
Finding 21: HQP acquired a varied range of skills and expertise from working on CRD projects, some of which are unique to collaborative R&D and contribute to their future work in the field. 49
Finding 22: After the CRD project, HQP primarily find employment in the private sector and in academia, and at least 10% are hired by the industrial partners. Factors such as the experience, expertise and skills gained through the CRD project help make HQP attractive hires in their field. 51

Finding 23: The majority of HQP benefit professionally from their CRD experience in terms of their career path, their reduced need for training and, in some cases, higher salaries. 53
Finding 24: Several long-term relationships between academic researchers and industrial partners have been established through the CRD program, with over 350 teams seeking further CRD funding. 55
Finding 25: Multiple lines of evidence indicate that the CRD program is efficient and effective, particularly in providing industrial partners with access to university research results and in leveraging private sector funds for collaborative R&D. 57
Finding 26: Improvements to the CRD program—such as through greater flexibility in fund use and partner cash contributions, adjustments to the application process and more program visibility—should primarily aim to enhance grant management efficiency and its breadth of impacts but should not affect fundamental aspects of the program's design or delivery. 61

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ABBREVIATIONS

ACUIG	Advisory Committee on University-Industry Grants
BIO	Food and Bio-Industries Sector (RPP division)
CRD	Collaborative Research and Development
DCM	Data Collection Matrix
E-NR	Environment and Natural Resources Sector (RPP division)
HQP	Highly qualified personnel
GDP	Gross domestic product
GSI	Gross static impact
IC	Industry Canada
ICM	Information, Communications and Manufacturing Sector (RPP division)
IP	Intellectual property
NSE	Natural sciences and engineering
NSERC	Natural Sciences and Engineering Research Council of Canada
NSI	Net static impact
R&D	Research and development
RPP	Research Partnerships Programs
SME	Small (fewer than 99 employees) and medium (100–499 employees) enterprises
S&T	Science and technology
STIC	Science, Technology and Innovation Council
TTO	Technology Transfer Office

1 INTRODUCTION

The Natural Sciences and Engineering Research Council of Canada (NSERC) mandated Science-Metrix to carry out the evaluation of its Collaborative Research and Development (CRD) program. The present evaluation report presents the findings of this evaluation as well as conclusions and recommendations that stem from these findings.

This introductory section of the Evaluation Report includes: background information on the CRD program (Section 1.1); description of the CRD program's main characteristics including its design and delivery, governance, key beneficiaries, and the CRD program logic model (Section 1.2); objectives and scope of the evaluation (Section 1.3); and evaluation questions (Section 1.4). The methods and data collection instruments are described and discussed in Section 1.6, whereas the key findings are presented by evaluation question in Sections 2 to 5.

1.1 CRD Program Context

NSERC invests in people, discovery and innovation for the benefit of Canadians. More specifically, NSERC supports the creation and transfer of knowledge and the training of highly qualified personnel (HQP) in the natural sciences and engineering (NSE) through strategic investments in Canadian science and technology (S&T). The strategic outcome of these investments is to support innovation through the "productive use of new knowledge in the NSE in Canada." NSERC not only supports basic university research but also funds research through partnerships among universities, governments and the private sector. Plans and priorities within NSERC—more specifically those of the Research Partnerships Programs (RPP)—therefore need to be considered when examining the CRD Program. The RPP is NSERC's leading mechanism to promote closer collaboration between the academic research community and Canadian industry, among other sectors.

In addition to being shaped by NSERC's policies and priorities, the CRD program falls under the umbrella of the Canadian government's plans and policies for S&T. Canada's innovation strategy (*Achieving Excellence* [2001]; *Mobilizing Science and Technology to Canada's Advantage* [2007]) strongly emphasises S&T collaborations between the business, academic and public sectors. Specifically, the latest S&T strategy identifies four research priority areas where Canada can leverage research strengths to gain a competitive advantage: environmental S&T, natural resources and energy, health and related life S&Ts, and information and communications technologies. In 2008, the Science, Technology and Innovation Council (STIC) identified sub-priorities in the four priority areas to assist research agencies in the design and implementation of research support programs.

1.2 CRD Program Rationale

The CRD program's objective is to give companies operating in Canada access to the unique knowledge, expertise and educational resources available at Canadian postsecondary institutions, and to train students in technical skills required by industry. The CRD program rationale is threefold: 1) to encourage the creation of partnerships between academic and industrial organizations in order to improve the application, the usefulness and the dissemination of knowledge; 2) to ensure that in years to come, Canada has an adequate amount of HQP with the skills needed by user organizations; and 3) to contribute to the capacity of industry to use academic research to improve the competitiveness and productivity of Canada and create jobs.

This program thus encourages mutually beneficial collaborations between companies and postsecondary institutions by supporting focused research and development (R&D) projects that generate industrial and/or economic benefits. More specifically, the CRD program grants support projects undertaken by university researchers in collaboration with private-sector partners. The direct project costs are shared by NSERC and the industrial partner(s).

1.2.1 Program Delivery

Projects eligible for support by CRD program grants may occupy any point on the R&D spectrum that is consistent with the university's research, training and technology transfer mandate. Grants are awarded to focused projects with specific short- to medium-term objectives, as well as discrete phases within a longer-range project. Most grants are awarded for a period of one to three years, but may last between one and five years. Projects are not eligible if they simply apply existing technology; provide routine analysis, professional practice or consulting services; collect data without interpreting underlying mechanisms; involve setting-up and operating an institute; or are principally associated with the acquisition and maintenance of scientific equipment.

Applications are submitted by the academic researcher (i.e., the 'applicant'), who must hold or have a firm offer of an academic appointment at an eligible Canadian university or college. All proposals require evidence of detailed planning and a sound budget. They may be submitted at any time during the year and are examined on an ongoing basis. NSERC staff is willing to review draft applications to provide feedback and guidance in the development of a complete application.

Applications that meet the program's eligibility criteria undergo a peer review. For large or complex applications, this review is performed by the Advisory Committee on University-Industry Grant (ACUIG) (for requests of $150,000 or more per year) and/or a site visit committee (for requests of $200,000 or more per year). Applications for the CRD program are evaluated on the following selection criteria: scientific merit, research competence, industrial relevance, private sector support, contribution to the training of HQP and benefit to Canada.

While there is no minimum or maximum grant amount, CRD program grants typically range from $10,000 to $500,000.[1] For every dollar, industrial partners contribute, on average, an additional $1.50 (a minimum leverage ratio of 1:1 NSERC-to-partner contribution ratio is required, with partner's cash contribution represent at least half of the NSERC request for each project). Partner eligibility guidelines are provided in the Program Guide for Professors;[2] in general, industrial partners are eligible if they are a Canadian-based business that is willing and able to exploit the research results for the economic benefit of Canada. Thus, multinationals may be eligible if they have commercial activities that take place in Canada, such as R&D or manufacturing related to the proposed research, and if the funded activity will result in significant economic benefit to Canada.

[1] The average CRD grant during the evaluation period was worth approximately $150,000; however grant amounts are not normally distributed, there being more small and mid-range grants than large grants. The median grant amount is approximately $90,000, and 75% of grants were less than $180,000.

[2] Full guidelines can be found on NSERC's website: http://www.nserc-crsng.gc.ca/NSERC-CRSNG/Policies-Politiques/orgpartners-orgpartenaires_eng.asp

Decisions on funding are usually made within three to five months of receiving the completed application. Between 147 and 262 new awards were granted each year between 1998–1999 and 2007–2008 (Table I), with an average success rate of 83%. Once awards have been granted, monitoring of CRD projects is achieved through annual progress reports (which can be waived for smaller projects), annual statements of expenditures and future costs, and mandatory final research reports.

1.2.2 Program Governance and Resources

The CRD program is located within the Research Partnerships Programs (RPP) Directorate of NSERC, which is led by the Vice-President, RPP. Within the Directorate, the program is administered by Directors, Portfolio Managers, Account Managers and Program Officers from three RPP Divisions (also referred to as "RPP Sectors"): Bio-Industries; Environment and Natural Resources; and Information, Communications and Manufacturing (ICM).

The CRD program's annual expenditures for CRD grants have ranged from $18M to $45M between 1998-1999 and 2007-2008 (Table I), with planned investments of approximately $46M per year until 2011-2012.

Table I Awards funded by the CRD program, 1998-1999 to 2007-2008

	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Total
New awards funded (count)	147	190	194	170	161	194	248	250	257	262	2073
New awards funded ($'000)	$8,358	$10,735	$10,355	$8,394	$8,695	$10,282	$12,493	$12,904	$14,386	$15,143	$111,745
Ongoing awards funded ($'000)	$10,395	$12,755	$12,585	$16,181	$17,909	$17,669	$17,185	$19,547	$23,195	$29,271	$176,692
Total awards funded ($'000)	$18,753	$23,490	$22,939	$24,576	$26,605	$27,951	$29,678	$32,451	$37,582	$44,414	$288,437
Total awards funded (count)	315	379	401	429	427	450	528	573	631	687	4820
Average per award ($'000)	$60	$62	$57	$57	$62	$62	$56	$57	$60	$65	$60

Source: NSERC Processing Report (as of October 26, 2009)

1.2.3 Key Beneficiaries

The beneficiaries of the CRD program are: industrial partners (also known as supporting organizations, see eligibility guidelines outlined in Section 1.2.1), academic researchers and HQP in the NSE. Canadian-based industrial partners benefit through the provision of access to the unique knowledge, expertise and educational resources available at Canadian colleges and universities. Conversely, academic researchers, benefit from financial support to create and disseminate new knowledge and technology, enhancements to their research and training, and the establishment of long-term relationships with industrial partners. In turn, HQP—especially undergraduate and graduate students—gain the opportunity to be involved in world-class research and to be trained in essential technical skills required by Canadian industry.

The 1,577 CRD grants that comprise the sample examined in this study (i.e., all CRD grants that had an end date[3] between April 1, 1998 and March 31, 2008) involved 1,196 unique industrial partners and

[3] The end date is the last date at which the grantee is permitted to make expenditures; note that this differs from the award closed date, which is when all reports are submitted and the grant file is closed by NSERC.

1,078 unique academic researchers. Several industrial partners and academic researchers participated in more than one CRD project during this period. The distribution of industrial partners based on the RPP sector and the size of the organization is presented in Table II.

Table II CRD industrial partners by RPP sector and organization size

	Partner size				
RPP Sector	Small	Medium	Large	Unknown	Total
Environment and Natural Resources	128	82	172	175	557
Food and Bio-Industries	131	42	51	62	286
Information, Communications and Manufacturing	112	76	157	135	480
Unknown	2	3	4		9
Total	373	203	384	372	1332

Note: Small: 1-99 employees; medium: 100-499 employees; large: 500 or more employees
Source: NSERC program data

1.2.4 Logic Model

A logic model for the CRD grant program developed by NSERC identifies the program rationale, activities and outputs, immediate outcomes, intermediate outcomes and final outcomes, as well as stakeholders (Figure 1). The logic model was developed in 2003 as part of a Results-based Management and Accountability Framework for RPP and is linked to the overall RPP Directorate logic model.

The outcomes of the CRD program are presented according to the time at which they are expected to occur. Immediate outcomes include those occurring before the notification of decisions ("pre-award") and that are critical to the success of the program, as well as those resulting from the activities and outputs of academic researchers and industrial partners collaborating on CRD projects ("during award"). Intermediate outcomes typically take place after the funding period for the CRD grant and include long-term benefits for academic researchers, industrial partners and HQP. Final outcomes represent the broad societal impacts of the CRD program, and are generally measured at an aggregate level with impacts stemming from other NSERC and government programs.

Industrial partners, academic researchers and HQP are clearly identified as the beneficiaries, particularly with regard to the intermediate outcomes. Additional stakeholders of the CRD program also include NSERC and the RPP, potential partners and applicants, reviewers, the scientific community, the user sectors (business, policymakers, NGOs, etc.), and the Canadian public.

1.3 Evaluation Context, Scope and Objectives

The CRD program was last evaluated in 1991 as part of an evaluation of all Research Partnership programs, with a follow-up study to the evaluation completed in 1992. In addition to this evaluation, follow-up surveys with academic researchers and industrial partners were conducted in 2000 and 2002 to assess longer term impacts, and a file review in 2002 led to revisions to the grant reporting templates. Given that the CRD program is a longstanding program and that the last full evaluation was performed a relatively long time ago, the primary focus of this evaluation is on the program's longer term socio-economic impact, particularly that on industrial partners (e.g., access to, and use of, university research; R&D activities and investments; productivity; job creation; competitiveness) but also on Canada.

INVOLVED GROUPS

Canadian public

User sectors (policy-makers, NGOs, business, etc).

Scientific community

Industrial partners

HQP

University researchers

Reviewers

Applicants

Potential partners and applicants

NSERC

RPP

FINAL OUTCOMES

- Stronger Canadian economy (FO5)
- Increase in evidence-based regulations and management practices (FO4)
- Increased employment opportunities for HQP in the NSE (FO3)
- Increased R&D investment by the industrial sector (FO2)
- Canadian companies and government are better positioned to use new technology (FO1)

INTERMEDIATE OUTCOMES

- Long-term relationships are established between academic researchers and industrial partners (INT4)
- The research and teaching of university researchers are enhanced as a result of the collaboration with industry and the reputation for quality and expertise held by Canadian researchers is improved (INT3)
- Industrial partners are aware of the benefits of university research, gain knowledge and technology as a result of collaboration and use research results (INT2)
- HQP obtain employment in their field and require less training once employed (INT1)

IMMEDIATE OUTCOMES

During Award:

- Researchers create new knowledge and technology and disseminate the results of their research to their partners and to the research community (IMM7)
- HQP conduct research in industrially-relevant environment and gain expertise relevant to industry (IMM6)
- Researchers use grants according to their project plan and budget, meet project milestones, and respect NSERC's rules on use of funds and financial accountability (IMM5)
- Industrial partners honour financial and resource commitments (IMM4)

Pre-Award:

- Reviewers, site visit committees, and ACUIG understand their role, recommend meritorious proposals for funding, provide feedback for the applicants and provide advice on the program and process (IMM3)
- Applicants submit proposals that meet CRD criteria and guidelines (IMM2)
- Partnerships and collaborations are formed between university researchers and industries to work towards common research goals (IMM1)

ACTIVITIES AND OUTPUTS

- Ongoing grant administration, monitoring, financial reviews and resolving problems (AO4)
- Presentation of recommendations on funding to NSERC management or ACUIG; Internal decisions are made based on ACUIG recommendations and applicants are informed of decisions (AO3)
- Applications are received and reviewed by external reviewers; site visits are conducted if necessary (AO2)
- Information on program reaches target audiences (AO1)

PROGRAM RATIONALE

- Encouraging the creation of partnerships between academic and industrial organizations in order to improve the application, the usefulness and the dissemination of knowledge.
- Ensuring that in years to come, Canada has enough highly qualified people with the skills needed by user organizations.
- Contributing to the capacity of industry to use academic research in order to improve the competitiveness and productivity of industry in Canada and to create jobs.

Figure 1 Logic model of the CRD program
Source: NSERC

In addition to success, evaluation issues pertaining to relevance, design and delivery and cost-effectiveness were examined for the 10-year evaluation period. This summative evaluation covers the period from fiscal year 1998–1999 to fiscal year 2007–2008. The evaluation itself was conducted between March 2009 and April 2010, with the bulk of data collection occurring between August and

December 2009. The projects examined in this evaluation have an end date within this period; the "end date" is defined as the last date at which the grantee is permitted to make expenditure. Thus, some projects covered by the evaluation will have been awarded a CRD program grant before 1998–1999, whereas some projects that received the award during the evaluation period were still be ongoing and not examined in detail. The justification for looking at projects after their end date is to improve the capture of intermediate outcomes, which typically take place after the funding period for the CRD grant.

The principal client for the evaluation is NSERC's President and Senior Management of the RPP Directorate. Additional clients are NSERC's Council and the Standing Committee on Research Partnerships. The evaluation was overseen and guided by an Evaluation Steering Committee, which was composed of evaluation and program staff from NSERC and a member of the Standing Committee on Research Partnerships. The stakeholders for the evaluation included CRD program management and staff, RPP senior management as well as CRD program key beneficiaries as identified in Section 1.2.3. The results of the evaluation will be used to demonstrate the impact of the program, to inform ongoing monitoring of program performance, to provide evidence in support of potential corrective measures to program design or delivery, and to inform future funding submissions prepared by NSERC.

1.4 Evaluation Issues and Questions

Evaluation questions that pertain to the four key evaluation issues (relevance, design and delivery, success/impacts and cost-effectiveness) were identified by NSERC evaluation staff as part of the planning process for the evaluation (Table III). These questions were developed in consultation with RPP senior management and CRD program staff, as well as with other individuals knowledgeable about university-industry research partnerships. During the consultation, respondents were asked to identify the most important issues for the forthcoming evaluation as well as prioritize questions that should be addressed.

1.5 Methods

This evaluation used multiple lines of evidence to address the evaluation questions and indicators identified in the data collection matrix (DCM). The following data collections methods were used: 1) document/data/file review (including review and analysis of administrative data such as that found in NAMIS and the results of past evaluation projects); 2) a grant file review, 3) 35 interviews (7 key informants and 28 for case studies); and 4) five web surveys. Moreover, two higher-level analyses made use of collected data: an economic impact analysis and six case studies. The last phase of the evaluation—meta-analysis and reporting—drew from all of the data collected and analyses performed in the previous phases. The full methodological approach is presented in the Methods section at the end of this report (page 66).

Table III Evaluation questions for the CRD program, by issue

Relevance: To what extent does the CRD program address a demonstrable need and respond to industry and academic researchers?

1. Does the CRD program continue to be consistent with NSERC and government-wide priorities in the area of science and technology?
2. Is there still a need for NSERC to fund research partnerships between academic researchers and industrial partners through the CRD program to give companies that operate from a Canadian base access to unique knowledge, expertise and educational resources at Canadian post-secondary institutions?
   - 2.1. Do the current objectives of the CRD program continue to respond to the needs of industrial partners and academic researchers?

Design and Delivery: What are the key factors for participation in the CRD program by industrial partners and academic researchers?

3. What factors facilitate or inhibit access to, and continued participation in, the CRD program by academic researchers and industrial partners?

Success/Impact: To what extent are the objectives and outcomes of the CRD program being effectively achieved?

4. What has been the impact of the CRD program on industrial partners?
   - 4.1. Based on participation in the CRD program, are industrial partners realizing the benefits of collaborating with academic researchers?
     - 4.1.1. To what extent have industrial partners gained knowledge and technology as a result of collaborations with university researchers? (INT2)
     - 4.1.2. How have industrial partners used, and benefited from, university research results? (INT2)
     - 4.1.3. How do industrial partners benefit from the collaborations with academic researchers beyond the direct use of research results?
   - 4.2. To what extent has the CRD program increased the following for industrial partners: competitiveness, productivity, and investment in R&D?
     - 4.2.1. Have there been additional economic, social or environmental benefits?
5. What has been the impact of the CRD program on university researchers?
   - 5.1. To what extent have researchers created and disseminated new knowledge and technology to industrial partners and the research community? (IMM7)
   - 5.2. What impact has participation in the CRD program had on university researchers' research? (INT3)
   - 5.3. What impact has participation in the CRD program had on university researchers' teaching? (INT3)
6. What has been the impact of the CRD program related to highly qualified personnel (HQP)?
   - 6.1. To what extent have HQP conducted research in an industrially-relevant environment? (IMM6)
   - 6.2. To what extent have HQP gained expertise and technical skills relevant to industry? (IMM6)
     - 6.2.1. What additional skills (e.g., professional skills) have HQP acquired?
   - 6.3. To what extent are HQP obtaining employment in their field? (INT1)
   - 6.4. To what extent, and in what capacity, are industrial partners hiring HQP involved in CRD projects?
     - 6.4.1. Are HQP involved in CRD projects more "job-ready"?
     - 6.4.2. Do HQP involved in CRD projects require less training once hired? (INT1)
7. To what extent has the program established long-term relationships between academic researchers and industrial partners? (INT4)

Cost-effectiveness: To what extent is the CRD program efficiently achieving its intended results?

8. Are the most effective and efficient means being used to deliver the CRD program?
   - 8.1. Can the efficiency of the CRD program be improved (i.e., can outputs be produced in a more affordable manner)?

1.6 Evaluation Challenges/Limitations

Most of the challenges and limitations that arose during the course of this evaluation are those inherent to any evaluation project, such as limitations associated with the methods that were used (e.g., interviews, surveys, case studies, review of program data). These types of challenges/limitations were mitigated to a large extent by experienced evaluators—both at Science-Metrix and NSERC—using best practices in evaluation and project management, including using multiple lines of evidence to support findings, internal verifications, regular progress reports, revisions to the project planning and schedule (when necessary), and other quality assurance measures. However, certain limitations occurred as part of the web surveys, economic impact analysis and case studies that were beyond the direct control of the evaluation team. These issues, which had a direct impact on the analyses that were used to inform this evaluation, are discussed below and, when relevant, in the results sections of this report.

A number of limitations arose with regard to the web surveys, more specifically issues with the sample population (i.e., very small population of unfunded respondents and large number of invalid email addresses for industrial partners) and with the sampling approach for HQP. This resulted in a fairly large margin of error for the unfunded industrial partners, which seriously limited the analysis that could be conducted using survey data for this group. With regard to HQP, because they were invited by academic researchers to participate, the survey sample was likely biased toward HQP who maintained contact with academic researchers. In both cases, analyses of the web survey data for the purpose of this evaluation took these limitations into account.

In addition, the small number of responses from unfunded web survey respondents, as well as issues with the numbers of blank or "not applicable" responses to certain key questions in the industrial partner web survey, had repercussions on the economic impact analysis. These analyses were very data intensive and so were directly limited by the availability and quality of the quantitative data from the web surveys. In particular, a bottom-up approach (see Section A.2.5) could not be conducted as part of the analysis of dynamic impacts of the CRD program. Some data from other sources (e.g., sample statements of accounts for CRD projects) were also challenging to work with in the context of these analyses. Moreover, certain factors that are inherent to the systems that were being modeled as part of the economic impact analysis and that are particularly key in the CRD program (i.e., the conduct of R&D in the business sector and higher education sectors, the role of students, the complexity of the innovation process) were carefully taken into account when conducting the analyses, and are clearly acknowledged in the interpretation of the findings.

Finally, the key challenge for the case studies was the selection of the six cases, which were required to meet the selection criteria (as outlined in Section A.2.6) and for which academic researchers, industrial partners and HQP had to be willing and available to participate in interviews. The sixth and final case study required the selection of a back-up choice for replacement of the original project, which resulted in a slight under representation of earlier CRD projects following a decision to prioritize a balance of case studies across RPP sectors. However, this does not diminish the validity of the case study findings.

2 KEY FINDINGS – RELEVANCE

To what extent does the CRD program address a demonstrable need and respond to industry and academic researchers?

2.1 Question 1: Consistency with government priorities

Question 1: Does the CRD program continue to be consistent with NSERC and government-wide priorities in S&T?

Both the document review and key informant interviews provided evidence that the CRD program and its objectives are consistent with current NSERC plans and priorities, particularly those related to strategic outcome 3.0 Innovation; "Productive use of new knowledge in the natural sciences and engineering." NSERC strategic planning documents and internal key informants also explained how specific steps were taken to align the CRD program with NSERC and government-wide priorities. Moreover, key informants within NSERC clearly indicated that the CRD program was seen as one of the "centerpieces" or "pillars" of the NSERC strategy to build university-industry partnerships for innovation. As such, NSERC has ensured the program was not cash-limited and increased industry outreach; this is meant to enhance the number and diversity of industrial partners involved in university-industry partnerships.

The RPP's Results-based Management and Accountability Framework and key informant interviews suggest that, while the CRD program is driven by the needs of industry, it was designed to provide added value for student training and HQP (strategic outcome 1.0 People; "Highly skilled science and engineering professionals in Canada")—especially as the training may include direct contact with industrial partners (see Section 4.3 for evidence of benefits to HQP). In addition, the program supports excellence in research through benefits to academic researchers (strategic outcome 2.0 Discovery; "High-quality Canadian-based competitive research in the natural sciences and engineering").

The focus of the CRD program on university-industry partnerships is consistent with wider government S&T priorities, as outlined in Canada's S&T and innovation strategies (e.g., *Achieving Excellence* [2001]; *Mobilizing Science and Technology to Canada's Advantage* [2007]), which strongly emphasise S&T collaborations between the business, academic and public sectors. For example, "Encouraging Partnerships" across sectors is one of the four core principles of the 2007 S&T Strategy. Moreover, key informants familiar with the S&T Strategy pointed to the alignment of the CRD program with the Strategy's 'Entrepreneurial Advantage'. The benefits that can be derived from public-private and other inter-sectoral collaborations—in terms of the commercialisation of research and the training of highly qualified individuals, for example—have also been discussed and demonstrated by a variety of reviews, both within and outside of Canada, and so these will not be re-examined here.[4]

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[4] See reviews from the UK, Canada and the US: Lambert, R. (2003) *Lambert Review of Business-University Collaboration*, Retrieved Oct. 2009 from: www.hm-treasury.gov.uk/d/lambert_review_final_450.pdf; Mongeon, M.D. (2008), *High Value University-Industry Interactions: A study of 20 interactions*, Mongeon Consulting; National Council of University Research Administrators (2006), *Guiding Principles for University-Industry Endeavors*, Retrieved Oct. 2009 from: http://sites.nationalacademies.org/xpedio/groups/pgasite/documents/webpage/pga_044335.pdf .

With regard to the four S&T priority areas (health and related life S&T; environmental S&T; natural resources and energy; and information and communications technologies) and Science, Technology and Innovation Council (STIC) sub-priorities, the three existing RPP sectors[5] under which CRD grants are administered cover the areas very comprehensively.

Nonetheless, this alignment can be said to have occurred "by default rather than by design": key informants from NSERC suggested that the CRD program was not changed in order to align strictly with the S&T priorities (or to target NSERC strategic areas) but, as it is responsive to all areas that address industry needs and thus operates in areas where the concentration of high-quality R&D already occurs in Canada, it is not surprising that there is a significant representation of the S&T priorities and STIC sub-priorities among CRD grants. The observation that CRD grants during the evaluation period were already aligned with S&T priority areas and STIC sub-priorities (which were announced in 2008[6]) is supported by the list of the most frequent "Areas of Applications" ascribed to CRD grants completed between 1997–1998 and 2007–2008. Indeed, the twenty most frequent areas, representing between 45 and 165 CRD projects each, include: Mineral resources; Forestry; Oil, gas and coal; Manufacturing processes and products; Environment; Pollutants and toxic agents; Human pharmaceuticals; Computer software; Life sciences (including biotechnology); and Information systems and technology. The CRD program thus inherently reflects S&T priorities.

Finding 1: The objectives and outcomes of the CRD program are clearly consistent with both departmental and government strategic planning, whereas supported projects reflect current S&T priorities.

The CRD program supports industry-university partnerships across the R&D spectrum and yet a large proportion of CRD projects are in the S&T priority areas. This suggests that elements of *flexibility* that are built into the program's design and delivery (see also Section 3.1) have helped to ensure the program's longevity. More specifically, the program's design has provided it with an ability to develop in a manner consistent with changing government priorities, as well as the means to adjust to shifts in the R&D areas covered by its key beneficiaries.

2.2 Question 2: Continued need

Determining whether there is a continued need for a program involves weighing the perceptions of individuals who have a stake in the program alongside other types of evidence as to the role the program plays, and would continue to play, in contributing to its objectives. Some of this evidence is derived from data collected on projects for which CRD applications were submitted but that did not receive a CRD grant: this counterfactual approach aims to draw conclusions about causation and relevance from cases when the potential cause did not occur (i.e., what happened in the absence of the CRD funding?). Efforts to collect data for the counterfactual analysis include examining the views and projects of unfunded applicants using the surveys and program data. More generally, the question of continued need is addressed with data collected from the web survey respondents (funded and unfunded), from key and case study informants, and from the review of program documents and secondary data.

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[5] Food and Bio-Industries; Environment and Natural Resources; and Information, Communications and Manufacturing

[6] Industry Canada (2008), "Minister of Industry Accepts S&T Strategy's Sub-Priorities Recommended by the Science, Technology and Innovation Council." Press release dated September 2, 2008.

Question 2: Is there still a need for NSERC to fund research partnerships between academic researchers and industrial partners through the CRD program to give companies that operate from a Canadian base access to unique knowledge, expertise and educational resources at Canadian post-secondary institutions?

Perceptions regarding the continued need to support collaborative R&D—whether these were collected via web surveys (Figure 2)[7] or key informant interviews—strongly suggest that stakeholders and others knowledgeable about the CRD program see a continued need for NSERC to offer this program. Key informants were unanimous in their view that the program should be continued, and some used this question to discuss ongoing efforts to increase industry "pull" for the program. Program stakeholders also believed that the CRD program was effective at initiating and supporting collaborative R&D projects between academic researchers and industrial partners.

> *"Left on their own, industry and universities tend to view themselves in competition with each other. But when opportunities such as CRD are presented to them, they pick up the phone and start talking to each other. It really goes a long way towards establishing communication and collaborations between two, traditionally disparate sectors." – Industrial partner*

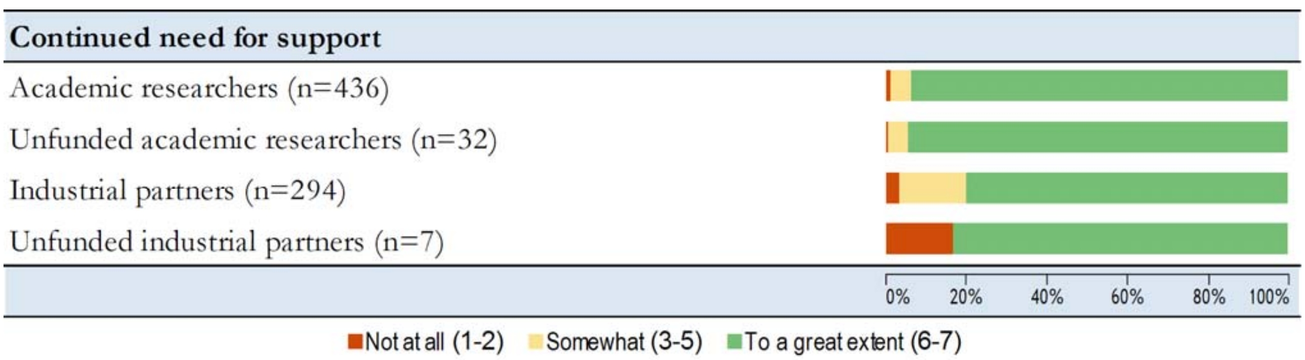

Figure 2 Perceptions regarding continued need to support collaborative R&D

Source: Web surveys of academic researchers (funded/unfunded) and industrial partners (funded/unfunded)

These findings suggest that significant change to (or the discontinuation of) the CRD program may be accompanied by a moderate-to-high level of risk for Canada since this program clearly fills a useful niche: the vast majority of stakeholders currently see value in the program and expect it to continue. In particular, some external stakeholders commented that: "Yes [there is a continued need for the CRD program], it's one of NSERC's real success stories. I would be alarmed if I were to hear that they wanted to stop it," and that "It's the very last [NSERC] program you'd ever want to cut."

[7] Responses rated on the 7-point scale are graphically presented in the present report in a manner that is consistent and comparable with the reporting approach adopted by NSERC in the follow-up telephone surveys conducted in 2000 and 2002: ratings of 1 and 2 are grouped under the category "Not at all", ratings of 3 to 5 are grouped under the category "Somewhat" and ratings of 6 and 7 are grouped under the category "To a great extent". Note that this differs slightly from the way in which the scale was presented in the surveys, where 1 corresponded to "Not at all", 4 corresponded to "Somewhat" and 7 corresponded to "To a great extent".

Meanwhile, the case studies suggest that the university-industry teams most often turned to the CRD program to obtain support for a collaborative R&D projects that had been previously envisioned. In these cases, the CRD program did not act as the main impetus behind the initiation of the project; instead, a project was proposed to address a need, and the CRD grant provided the support necessary for the project to proceed—and often to proceed on a broader scale than would have been possible without NSERC funding. One of the important roles of the program is to provide a vehicle to help academics initiate discussion with industry regarding collaboration:

> *"This program is great for providing academic researchers with the incentives and framework to work with industrial partners. Industry can be difficult in that they often won't initiate collaborations on their own. This program gives researchers the chance to go to industry with money already on the table… it helps to draw their interest." – Academic researcher*

The CRD value-added also included involving and training HQP, increasing the scope and scale of the research and/or its applications (i.e., longer-term and more open-ended nature than the comparatively focused corporate R&D), and allowing multiple industrial partners to participate in and benefit from individual or consecutive collaborative R&D projects.

When asked about aspects in which the support for collaborative R&D between university researchers and industrial partners is lacking, some academic researchers felt that Canadian industries should be encouraged to increase their R&D spending. There is also a perception among this group that industrial partners are more willing to provide in-kind contributions than cash contributions, and that a funding program that allows for increased recognition of in-kind contributions would be of interest to both researchers and industrial partners. As for industrial partners, several saw a need for a means to support the visibility of the CRD projects and programs, including greater outreach into the industrial community.

Finding 2: CRD program stakeholders see a strong continuing need for the program, and consider it an effective means to initiate and support university-industry collaborative R&D projects.

The need for ongoing support from NSERC for collaborative R&D projects between university and industry was also assessed by examining the reach of the CRD program in Canadian industry and the extent to which the CRD program was solicited relative to other means of support.

The reach of the CRD program in Canadian industry was assessed using Research InfoSource's annual list of Canada's Top 100 Corporate R&D Spenders (for the years 1999 to 2008) and program data; more specifically, the analysis examined the extent to which the CRD program has been utilized by the corporations on this list. Among the 204 corporations that appeared on this list at least once during this 10-year span, 44% were an industrial partner on at least one CRD project during the evaluation period. This represents a total of 673 grants, or 43% of all grants that ended within this period. Among the firms that appeared most often in the list (i.e., at least three years during the ten years examined), the reach of the CRD program was even greater: 55% participated in at least one CRD project. This percentage continues to increase with the number of times the firm is listed: 63% for firms listed five or more years, and 78% for firms listed eight or more years. Interestingly, the CRD program's reach into the top R&D spenders in industries that are related to the Environment and Natural Resources RPP sector (e.g., mining, oil and gas, forestry) was greater than for Food and Bio-Industries and ICM sectors;

this difference could be related to several factors (e.g., number/structure of firms in each sector, boom and bust in ICM during the period under review).

The relative importance of CRD program funding to total project funding was assessed using program data and data from the web surveys. Program data reveal that CRD project funding represented 39% of total project funding when considering both cash and in-kind contributions, or 53% of the total project funding when considering cash alone. Moreover, according to respondents to the academic researcher survey, about one quarter of CRD projects received additional funding that was not matched by the CRD program. This funding was most often obtained from industrial partners, provincial governments or other NSERC grants. These non-matched amounts were often small (less than $50,000) but occasionally surpassed $500,000. It is important to note that some contributions made to CRD projects, such as those obtained from provincial governments or other NSERC grants, are not eligible for matching CRD program funds (e.g., contributions from non-eligible organizations, certain indirect costs of research).[8] This suggests that CRD program funding represents a key source of support for these projects, especially cash support.

Web survey respondents (academic researchers and industrial partners) were also asked what programs and funding sources they had accessed to support collaborative R&D projects. The results suggest that researchers will often return first to the CRD program to support subsequent projects (either on the same or on different research), followed by other NSERC grants. Interestingly, some researchers have accessed funding offered through research network programs of the federal and provincial governments, such as the Networks of Centres of Excellence (e.g., Auto 21, AquaNet), the Ontario Centres of Excellence (e.g., Centre for Communications and Information Technology, Centre for Microelectronics Assembly and Packaging), and funding offered by provincial research councils (e.g., Ontario Research Fund, Conseil des recherches en pêche et en agroalimentaire du Québec). Other notable mentions are projects funded by the Canadian Space Agency and by the Consortium de recherche et d'innovation en aérospatiale au Québec (CRIAQ, a non-profit university-industry research consortium).

In contrast, industrial partners most often drew on their own funds to support subsequent projects, followed by other NSERC grants and CRD grants. Other government programs used by industrial partners to support collaborative R&D projects with academic researchers were primarily R&D grants (49%), technology support and assistance (28%), and support for training (16%).

Analysis of the case studies suggests that many university-industry partnerships turned to the CRD program when it became apparent that the industrial partners did not have the financial capacity to support the research alone, or when the costs of the project were prohibitive in light of the degree of risk involved if the research results could not be commercialized.

> *"Our industry is used to commercial development and implementation costs but not so much the costs for fundamental research. Our budget would never have permitted us to exclusively support [the academic researcher's] efforts in this endeavor and it would have been a tremendous loss." – Industrial partner*

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[8] For more details see NSERC's Program Guide for Professors, particularly the 'Guidelines for Organizations Participating in Research Partnership Programs' and, more generally, 'Use of Grant Funds' guidelines.

Funded researchers and partners were also asked, through the web survey or the follow-up telephone surveys, to indicate the likelihood that their CRD project would have proceeded in the absence of CRD funding. Across data sources, the data consistently suggest that, at most, one third of the projects submitted for a CRD grant would have taken place without the grant. Of the 112 industrial partners who indicated (via the web survey) a greater than 50% chance of proceeding without CRD funds, 55% said their organization would have contributed financially, whereas academic researchers would have relied primarily on contributions from industrial partners or other NSERC grants. Data from the follow-up telephone surveys supports these findings. In addition, many respondents said (with or without being asked) that the unfunded project would have been reduced in scope.

This is largely supported by the unfunded researcher surveys: of the 32 unfunded projects referred to by academic researchers 19 projects proceeded, 5 projects proceeded in whole (16%) and 14 proceeded in part (44%). Projects that proceeded in part were reduced in scope, or it simply became a different type of project (e.g., research contract, no participation of industrial partner). Nonetheless, industrial partners contributed (cash and/or in-kind) in 17 of these 19 cases, suggesting that the projects generally maintained the industry focus. However, survey results show that unfunded projects involved less HQP participation and had less of an impact on research.

Finding 3: Academic researchers and industrial partners continue to rely (to a substantial extent) on the CRD program to support their collaborative R&D projects. The extensive reach of the program throughout Canadian industry and the restricted scope and impact of projects that did not receive CRD funding also suggest that it occupies an important niche among alternative sources of support in Canada.

Question 2.1: Do the current objectives of the CRD program continue to respond to the needs of industrial partners and academic researchers?

The CRD program is perceived by interviewees as a key "tool in the toolkit" (including programs offered by NSERC and in Canada more generally) to support collaborative R&D projects between academic researchers and industrial partners that are mutually beneficial. This perception is shared by both internal and external key informants, who identified several specific needs of industrial partners and academic researchers that are met (and, in a few cases, not met) by the program, and discussed how some of these needs have changed over time. The views of interviewees are consistent with the evidence collected from the beneficiaries themselves (also indicating that key informants are in tune with the communities served by the program), particularly with regard to broad "organizational" needs (e.g., reduced financial risk for industrial partners). As such, the following discussion will focus on the data collected through the web surveys of academic researchers and industrial partners, with additional examples drawn from the case studies and corroboration using findings from the follow-up telephone surveys conducted during the evaluation period.

Academic researchers

Almost 400 academic researchers identified over 800 individual needs in their web survey responses. Of these, more than half (52%) received a rating of 6 or 7, where 1 indicates that a need that is not at all met and 7 indicates that a need has been met to a great extent. Approximately 20% of the needs that were identified were not met, i.e. they received a rating of 1 or 2. When ratings were broken down according to relevant variables (i.e., region, year researcher obtained doctoral degree[9] and institution size), it emerged that respondents from regions other than Quebec, Western Canada and Ontario identified the highest proportion of unmet needs, as did respondents from small institutions; there was no difference in the ratings based on doctoral year.

The evidence strongly suggests that the CRD program has responded very well to a wide variety of needs of academic researchers. Not surprisingly, "funding" was most frequently identified by academic researchers as a need that is being met by the CRD program. The program funding and the CRD program more generally was said to enable four main types of activities that are valued by academic researchers (in order of prevalence):

1) involvement and training of HQP;
2) industrially relevant research and technology transfer;
3) leveraging of additional funds from industry; and
4) fundamental research that complemented the applied aspects of the research.

In meeting these needs, the CRD program is seen by some as occupying a key niche. More specifically, opportunities for HQP were repeatedly cited as being an important need being met by the CRD program, as were opportunities for building mutually beneficial relationships with industrial partners (both of which can lead to future or greater opportunities for HQP and the university-industry team). These mutual benefits include providing industrial partners with the benefits of academic research and a lower level of risk on R&D projects, whereas academic researchers increase their access to industry funds, data, equipment, materials and "real-world"/relevant problems all the while retaining the freedom to conduct basic research and publish their findings. Evidence was also found of the ways in which the needs of academic researchers are being met by the design and delivery of the CRD, including the program's flexibility (in terms of year-round applications, project duration, funding level, and research fields) as well as the streamlined application process, fast review and assistance of NSERC staff. Finally, some academic researchers also recognized the responsiveness of NSERC and applauded changes made to the CRD program during the ten years of the evaluation period.

Evidence of the CRD program *not* meeting needs identified by academic researchers was also found. These types of needs that are considered not to be met by the program are listed below in conceptual groupings; the first list presents the five most prevalent issues and the second list comprises complementary issues that were occasionally raised by researchers when asked about unmet needs and suggestions for program improvements. Note that some issues in both theses lists (particularly those regarding the definition of industrial partners and the eligible types/areas of research) may stem in part from misunderstandings on the nature and objectives of the CRD program, or may have already been addressed by recent modifications to the design and delivery of the CRD program.

- Better support or mechanisms (programs/services) to establish relationships with industrial partners (including tools to find partners, exchange programs between universities and industry, outreach/education) and to increase industry awareness and buy-in;

[9] This variable is a proxy measure for the experience level of the researcher.

- Seed funding to start collaborations with industry partners or mini-CRD grants, to support preliminary/early-stage/exploratory work (this would be especially helpful to encourage industry buy-in for a full CRD and would ideally involve mainly in-kind contributions from the industrial partner), especially for small to medium companies;
- Streamlined application and reduced reporting requirements;
- More flexibility with regard to program eligibility requirements (including for types/timing of HQP, allowing the participation of industrial partners that do not have an R&D base in Canada, and broadening the eligible type/areas of research); and
- More flexibility with regard to funds (e.g., greater/more flexible matching of in-kind contributions, greater level of funding, higher ratio of CRD funds to industry funds, use of CRD funds for equipment/tools, faster advancement of funds by NSERC, etc.).

Additional issues include:

- Increasing support from university and/or banning overhead charges by university;
- Increased assistance and/or funding for IP (agreements, costs, etc.);
- Increased or more accessible funding for equipment and infrastructure; and
- Extending funding and/or providing follow-up funding, both for education, transfer and/or commercialisation, and to support knowledge/technology transfer more generally (including patenting activity, to develop business opportunities and spin-offs), particularly for smaller companies.

In terms of unmet needs that were common in certain regions or according to the size of the academic researcher's institution, there appears to be an increase in the need for (a) support in finding and/or building relationships with industrial partners, and (b) a higher level of industry awareness and buy-in in "other regions" (i.e., Maritime provinces and Saskatchewan) and in small or medium-sized institutions.

Industrial partners

As for industrial partners, almost 300 identified slightly fewer than 500 individual needs, 56% of which were claimed to have been met (ratings of 6 and 7), and 11% of which were not met (ratings of 1 or 2). Web survey respondents whose projects were in the Food and Bio-Industries sector identified a higher proportion of unmet needs than those from the two other RPP sectors. There were no conclusive differences in ratings based on the size of the industrial partner (i.e., number of employees).

Similar to the findings concerning academic researchers, the evidence also suggests that the CRD program generally responded well to the wide variety of needs of industrial partners. Industrial partners often confirmed that their collaborative R&D projects achieved their expected technical goals. In addition, the following needs were most often reported as being met by the program:

- Access to the knowledge, expertise and facilities/equipment of Canadian academic institutions, especially when these are not available in-house;
- Training of HQP in relevant areas of research and access to HQP as potential future employees;
- Opportunities for networking and development of partnerships between industry and academics;
- Fundamental/basic/early research in areas of interest to the industrial partners;
- Ensure the maintenance of world-class academic researcher teams/facilities in areas of interest to industrial partners;
- Leveraging of funding (and offsetting costs) for R&D of interest to industrial partners; and
- Support innovative and high-risk R&D that is difficult to justify/support by industry alone (i.e., risk reduction).

Many of the needs identified by industrial partners as *not* being met by the CRD program (i.e., rating of 1 or 2) related to the development of new products, services, processes and other R&D outcomes that relate specifically to their field or area of application but that were beyond the scope of the current CRD project (e.g., fish transport research, evaluation of effects of bioenergy, and more efficient production methods). In terms of needs that relate more specifically to the goals of the CRD program, industrial partners felt the following needs could be better met:

- Networking opportunities and ways to identify potential academic researchers for collaboration;
- Flexible IP agreements that allow industry to own IP;
- Faster/simpler application process; and
- More funding for collaborative research (in addition to that which can be provided by CRD program as per program guidelines, funds from other sources, etc.).

Moreover, a few industrial partners echoed several of the issues raised by academic researchers such as allowing for greater matching of in-kind contributions, assistance in follow-up/implementation of the CRD project results, greater flexibility in terms of partner eligibility, and greater opportunities for industrially-relevant training of HQP.

Industrial partners identified 125 needs that have been somewhat met by the CRD program (i.e., ratings of 3 to 5), which covered all of the issues which received a rating of 1 or 2, as described above. However, there was a greater emphasis on describing needs for R&D outcomes that would be of benefit to their organization, such as increased internal R&D capacity and ability to solve problems, development of new technologies and/or commercially viable results, and applied research more generally. Industrial partners also listed a number of needs that related to the access of knowledge, expertise and resources of Canadian post-secondary institutions, particularly with regard to access and other opportunities for HPQ, as well as reduced risks (financial or otherwise) of research and innovation, and indicated that many of these needs were only somewhat met by the CRD program.

When examining unmet needs identified by respondents according to their RPP sector, two trends emerged: first, industrial partners in the ICM sector identified more unmet needs (rating 1 or 2) with regard to the management of intellectual property, whereas those in the Food and Bio-Industries were more likely to indicate a need for greater support in identifying and linking with appropriate academic researchers.

Finally, it should be noted that evidence with regard to the trends of growing participation in the program (i.e., number of grants and number of individual partners) and steady increase in the partner contributions (cash and in-kind) attest to the fact the program responds to the needs of its beneficiaries. One case study in particular involved a consortium of industrial partners who have been working with the academic researchers on a series of projects for almost 20 years—since few companies fund long-term projects without a clear return on investment, this long-term relationship indicates a perception in industry that this work is valuable. Also, the fact that the program is not cash limited helps ensure, first, that the program can grow in this manner, and, second, that the needs of its growing population of key beneficiaries can be met.

Finding 4: The CRD program responds to a large proportion of the needs identified by industrial partners and academic researchers, although a small number of outstanding needs may still exist, both overall and for certain sub-groups of researchers and partners.

3 Key Findings – Design & Delivery

What are the key factors for participation in the CRD program by industrial partners and academic researchers?

3.1 Question 3: Factors that facilitate or inhibit access and participation

This section focuses on factors that facilitate or inhibit access to the program, with a view to verifying whether the CRD program's design and delivery contribute to facilitating access or to lessening the effect of factors that inhibit access. Balancing the views of key informants (both internal and external) with those of program beneficiaries is crucial here, as the expectations of program beneficiaries are likely to overextend what the program can realistically offer. The most obvious example of this are the few instances in which academic researchers or industrial partners indicate that the program would be more accessible to them (or would better respond to their needs) if collaboration with the other group were not required; clearly, offering this option would go against the very nature of the CRD program. As the issue of the relevance of the CRD program and its objectives has been comprehensively covered by the two first evaluation questions, the following analysis will be limited to factors that acknowledge the current objectives of the program.

Question 3: What factors facilitate or inhibit access to, and continued participation in, the CRD program by academic researchers and industrial partners?

In the web surveys, academic researchers (both funded and unfunded) and industrial partners were asked to rate—on a scale of 1 to 7 where 1 means "greatly inhibits" and 7 means "greatly facilitates"—a series of factors that may affect their ability to access the CRD program. In all cases, "pre-established relationships with industrial partners [or academic researchers]" was the factor that most facilitated participation in the CRD program (Figure 3). Similarly, past positive experiences with the program help incite academic researchers and partners to pursue subsequent CRD grants; case study findings also strongly supported this finding. Several web survey respondents also pointed out that not all pre-established relationships are created equal, and that affinities between the individuals concerned can help overcome the "culture gap" between industry and academia.

Conversely, all three groups of survey respondents (industrial partners, funded academic researchers, and applicants who were not funded) indicated that the requirement to find an industrial partner willing to make a cash contribution (or in the case of the industrial partners, the requirement to make a cash contribution) was the factor that most inhibited access to the program. Academic researchers who received funding gave a similar overall rating to the rest of factors in the list, whereas the unfunded researchers indicated more often that their ability (or lack thereof) to find an industrial partner inhibited access to the program (Figure 3A). Industrial partners rated very few other factors as "inhibitors", but the extent of their R&D activities and their ability (or means) to find academic researchers were relatively more important than the other factors in the list (Figure 3B).

Respondents were also given the opportunity to identify other factors that could inhibit or facilitate their access to the program. According to academic researchers and industrial partners, the main facilitating factors were the availability of and access to HQP, the relevance of research to industry, the assistance from co-applicants or certain industrial partners (e.g., industry associations) and access to facilities (e.g., at the academic institution, at the partner organizations, or at a participating research centre).

Figure 3 Factors that facilitate or inhibit access to the CRD program for A) academic researchers (funded and unfunded) and B) industrial partners.

Note: Factors are listed based on a weighted average of ratings given by survey respondents, starting with the most facilitating factor; in Figure A, the order is based on the ratings of funded academic researchers.

Source: Web surveys

Two of the case studies highlighted ways in which university-based assistance, either within the researcher's department or within the institution's technology and research transfer office, helped the applicant become aware of the CRD program, its advantages and its requirements. The existence of "gateway" organizations or programs—such as Ontario Centres of Excellence or other networks/organizations/programs that bring together researchers and partners and help broker CRD grant applications—may also represent an opportunity to expand the reach of the CRD program by supporting the development of links between potential university-industry teams.

> *"I was able to take advantage of a simplified application procedure for projects recently approved for funding by CITO (Communications and Information Technology Ontario, now part of OCE)." – Industrial partner*

In contrast, the most common inhibiting factors were clearly intellectual property (IP) agreement/management issues (particularly with regard to establishing/managing IP agreements with academic institutions), the fact that the program limits eligible partners to Canada-based organizations (this may include multi-nationals who have commercial activities that take place in Canada; see Section 1.2.1 for more information on partner eligibility), and lack of support from the researcher's institution. However, some comments in the web surveys suggest that recent changes in NSERC's IP policy and current partner eligibility guidelines are perhaps not well understood; this represents an opportunity for greater education and understanding of the CRD program among external key stakeholders.

Key informants, including managers within NSERC (RPP- and program-level), members of the ACUIG and TTO representatives, also provided insight into key factors. When asked about facilitating factors, key informants often identified elements of the design and delivery of the program that had also been identified by web survey respondents as aspects of the programs that met their needs (see Section 2.2). For example, the flexibility built into the program was praised by both key informants and survey respondents, including the fact that submissions are accepted and reviewed year-round, that eligible projects span the R&D spectrum, and that these are unconstrained by specific/narrow priorities or industrial sectors. Key informants also felt that the stability/consistency of program over many years was a facilitating factor, as was the program being well known and well understood by program staff, program beneficiaries and program "brokers" such as university-industry liaison offices. It is also likely that the program's high success rate for applications (approximately 85%) acts an incentive: university-industry teams are more likely to apply if they know there is a high likelihood of obtaining a grant. Note that this high success rate is due to the fact that applications can be submitted at any time (i.e., proposals are examined on an ongoing basis), industry has already vetted the proposal and found it of high enough quality to support with cash, CRD program staff review and provide feedback on draft applications in an iterative manner (see also Section 1.2.1) and that applicants are sometimes given the opportunity to respond to negative peer review evaluations.

Finding 5: The existence of pre-established relationships between academic researchers and industrial partners (or "gateways" that help forge these relationships), combined with the flexibility built into the design and delivery of the CRD program, are key facilitating factors for program participation.

Internal key informants were also able to shed light on aspects of the CRD program's design and delivery that were deemed less positive. In particular, they echoed the web survey respondents in saying that issues remain surrounding IP management despite the recent changes made to NSERC's IP policy. As shown below, these changes are generally viewed as positive; however, certain IP management practices involving universities and the lack of standard IP agreements (i.e., agreements that could be re-used and so save considerable time and money) remain problematic.

> *"Ownership of IP developed [was rated as an inhibiting factor]. This has now changed, but previous NSERC policy of requiring the academic institution to own all IP was a showstopper for us in making use of the CRD program." – Industrial partner*

One aspect that may also help to address the IP issue concerns the visibility (or lack thereof) of the CRD program among various industries and the lack of experience of industrial partners regarding collaboration with universities, including IP management. In the web survey, academic researchers—particularly researchers from "other regions" (i.e., Eastern Canada) and those working in small or medium-sized institutions—identified the need for greater awareness of and buy-in for the CRD program in the industrial sector (see Section 2.2). Moreover, small and medium-sized firms were also seen—by some researchers and other informants—as being more likely to lack experience and established processes for collaborating with universities. Note that it is difficult to gauge the degree to which potential industrial partners are aware of the CRD program, as this evaluation did not interview or survey industry partners that had not participated in at least one CRD application.

Another factor that may inhibit participation in the CRD program is the application process, which involves the same amount of paperwork and turnaround time no matter the size of the grant[10] – this is significant, as CRD program grants typically range from $10,000 to $500,000. Hence, university-industry teams may be less likely to apply for CRD funding if their project is small (e.g., representing an amount of less than $50,000) or short-term.

> *"The application process for a CRD grant was the same rigor for a project worth $20,000 as it would be for a project worth $250,000. This does not seem correct to me. I ended up with forms that totalled the same length as my discovery grant, even though I only received 1/5 of the funds from NSERC" – Academic researcher*

It was suggested that smaller projects might also generate fewer results or less impacts, but small projects may also be over-represented in certain groups. For example, the Maritime Provinces have a greater proportion of small and medium enterprises (SME) that participate in CRD projects than other Canadian regions, as well as a greater proportion of small institutions than Quebec or Western provinces. Alternately, new faculty members (non-tenure) may be less likely to be able to embark on multi-year projects, whereas organizations that may have never collaborated with academic researchers on an R&D project may be less likely to embark on a large or long-term project. As such, it was suggested by key informants and survey respondents that a streamlined application process could be introduced for smaller CRD grants, especially to facilitate the participation of certain sub-groups of program beneficiaries. An opportunity to develop this streamlined process could exist within the context of a "pre-CRD" grant pilot program that is currently begin examined, as outlined in NSERC's Report on Plans and Priorities 2009-2010 (pg. 28):

> *"NSERC will explore a Pre-Collaborative Research and Development (Pre-CRD) grant pilot program, with a reduced requirement for partner contribution, to increase the number of university-industry interactions and partnerships. NSERC's experience has shown that successful long-term collaborations often begin first as a small joint CRD project that tests the value of the university-industry relationship."*

This "pre-CRD" grant pilot program would also address needs as identified by both academic researchers and industrial partners, namely reduced cash requirements and/or greater matching of in-kind contributions and mini-CRD/seed funding (see Section 2.2).

Finding 6:	Factors that inhibit participation in the CRD program include the cash requirement for industrial partners, IP management issues (in spite of adjustments made to NSERC's IP policy), and the workload and timeframe involved in the application process for small/short-term CRD projects.

[10] Note that the Advisory Committee on University-Industry Grants reviews all applications requesting $150,000 or more per year and that site visits are required for applications requesting $200,000 or more per year.

4 KEY FINDINGS – SUCCESS/IMPACT

To what extent are the objectives and outcomes of the CRD program being effectively achieved?

4.1 Question 4: Impact on industrial partners

Industrial partners are the primary beneficiaries of the CRD grant program and therefore the assessment of the program's impact on this group is an important aspect of this evaluation. It should be stressed here that the CRD program, by virtue of its flexible nature (e.g., supporting projects that vary in size, scope, industry type, and industry size, not to mention that span the R&D spectrum), is expected to generate a wide range of impacts; as such, few grants will lead to the full range of impacts that are described in the present section, nor should they be expected to. However, all (or a very large proportion) of CRD projects should bring some measure of benefit to the industrial partner(s) in order to support ongoing industry participation in, and increased industry "pull" for, the program.

Question 4: What has been the impact of the CRD program on industrial partners?

Evidence on the overall impact and benefit of CRD projects as perceived by industrial partners (a perception that is supported by other lines of evidence) clearly indicates that partner organizations derive value from these projects. A high level of achievement of project objectives is consistently reported by the majority of industrial partners: indeed, on a scale of 1 to 7 (where 1 means that the objectives were not at all achieved and where 7 means that the objectives were achieved to a great extent), industrial partners gave an average rating of 5.9. This same average rating was found both in responses collected immediately at the end of the project (as measured in the review of grant files) and collected up to 10 years after the end of the project (i.e., in the web surveys). Moreover, over 93% of web survey respondents agreed that their CRD project was a worthwhile investment for their organization, compared to 96% of industry respondents in a 2002 two-year follow-up survey.

Based on the file review of CRD grants that ended in 2006–2007 and 2007–2008, only 6% of partners stated that they were not satisfied with the outcome of the project, whereas almost 20% of projects were assessed to have had a significant impact on the operations of industrial partners.[11] Several examples from the case studies illustrate the variety of ways that industrial partners defined project objectives, against which they measure their satisfaction with the project's outcome. While all six projects in the case studies met their specific technical objectives, their application was not always realized. For example, in one of the cases, the research results exceeded the technical expectations of the industrial partners, although the end-product could not be commercialized because: 1) the materials in the end-product interacted in novel ways such that additional testing would have been necessary to obtain approvals for safety and usage and 2) its appearance was deemed off-putting to customers.

In another case, the results were not immediately applicable, but the industrial partners recognized that the outcome of the CRD project "should be considered the initial stepping-stone on a much longer path to a product that we in industry could use on a routine basis." This project was followed by two other

[11] This assessment is conducted by the program officer based on a review of the partner comments.

CRD grants, the results of which are now providing industrial partners with tools they can use in real-life situations; industrial partners thus recognize that both of the latter two projects have firm roots in the first CRD project. Moreover, three of the six CRD projects examined provided clear examples of cases in which both the technical objectives and the contribution of research results to subsequent industrial applications and impacts achieved (with a high potential for more), for example, increased cost-effectiveness and competitiveness, to the great satisfaction of the industrial partners.

> *"The software has been extremely valuable [and] is used daily by [the industrial partners, some of which] will not drill a hole without having used this technology. The exploration industry for minerals relies very heavily the kinds of codes that have been put together." – Academic researcher*

Finally, in another case, sustaining a source of talented individuals who can join the workforce and contribute to development in their region was the industrial partner's primary objective in funding the project, and they had "no strong interests one way or the other regarding the actual research objectives." The industrial partner was very satisfied with the numerous HQP who were trained at their facilities during the project and with the industrial relevance of the skill sets being developed by the HQP; many of these HQP have since been employed within the oil and gas industry.

Thus, the success and impact of CRD projects can take many forms; the program's flexibility and capacity to produce such a range of benefits for industrial partners (in accordance with their needs, and sometimes exceeding these needs) should be considered as a key strength of the program. The program requirement that CRD projects must be focused helps direct and evaluate the achievement of technical objectives in the short term, but many impacts of the projects clearly occur in the longer term.

Finding 7: Industrial partners are deriving tangible benefits from the CRD program, even in cases where technical setbacks are encountered.

Question 4.1: Based on participation in the CRD program, are industrial partners realizing the benefits of collaborating with academic researchers?

When industrial partners were asked to identify their needs and rate how the CRD program met these needs, the "organizational" needs that were most often given a high rating were:

- Access to the knowledge, expertise, facilities/equipment of Canadian academic institutions, especially when these are not available in-house;
- Access to fundamental/basic/early research in areas of interest to the industrial partners; and
- Maintenance of world-class academic researcher teams/facilities in areas of interest to industrial partners.

This suggests that many industrial partners are realizing the benefits of collaborating with academic researchers. Additional evidence from the web surveys include the fact that most industrial partners reported a high level of satisfaction with academic researcher partnerships: three quarters rated the success of their partnerships as a 6 or 7 (on a scale of 1 to 7, where 7 means a "to a great extent") and only less 3% rated it 1 or 2 (where 1 means "not at all"). In fact, over 90% said the expertise of the researchers and their good working relationship contributed to the achievement of project outcomes; this underscores the need to foster communication and relationship-building between these two groups.

Of course, these represent the views of industrial partners who have already participated in at least one CRD project. It would be interesting to obtain information from industry organizations who have not participated in any CRD projects in order to better understand the reasons why they may choose not to collaborate with academic researchers: is it because they do not have a need to do so, or because they have not yet realized the benefits of doing so? A 2004 review of surveys on private sector views on university-business interactions concluded that "the benefits of working with university researchers have to be made more obvious, otherwise SMEs won't invest as their resources are limited."[12] This suggests that an opportunity may exist to increase the awareness (and subsequent buy-in or "pull") of industry organizations in the CRD program; this is also a need that was identified by academic researchers. This conclusion is consistent with findings from NSERC's Strategy for Partnerships and Innovation, which was based on broad consultations with industry, academia and government (including representatives from businesses that have not participated in NSERC programs). For example, individuals from both industry and academia reported the need for: more information on the other sector's strengths; more opportunities to build relationships before entering into research collaborations; and help for companies to identify/approach university/college researchers, build relationships and develop collaborative proposals.[13]

Strong evidence regarding the participation of industrial partners in CRD projects points to an ongoing interest in collaborative R&D and ongoing collaboration among this group. For example, approximately 70% of partners originally planned future collaborations with academic researchers, whereas 75% reported ongoing collaborations with researchers after the CRD project. Over 60% of these collaborations involved the same researchers, whereas 50% involved new researchers. In one of the case studies, the CRD grant examined is actually only one of a series of CRD grants involving a large industry consortium; this collaborative relationship spans a twenty-year period. The relationship with the industry consortium will be continued after the retirement of the academic researcher who originally established the partnership by another professor (and a current NSERC Industrial Research Chair) who first became involved with the consortium as an HQP on one of the prior CRD grants.

Moreover, there is evidence that academic researchers may be increasingly realizing the benefits of collaborative R&D with, and the benefits of the CRD program more generally. Indeed, 25% of industrial partners who were involved in a CRD project during the evaluation period have participated in more than one CRD project (299 out of 1,196). Moreover, NSERC's 2009-2010 Departmental Performance Report indicates that the number of organizations participating in the CRD program increased by 23% since 2004-2005.[14] This increase is largely due to the sizeable rise in the number of small enterprises (i.e., those with fewer than 100 employees) who have participated in CRD projects since 2004.

Finding 8:	Based on their high levels of satisfaction with and continued participation in collaborative R&D projects with academia, industrial partners are realizing benefits from these collaborations.

[12] Riddle, C. (2004) Commercialization Strategies of Canadian Universities & Colleges: Challenges at the University/College – Industry Interface, A Study for The Advisory Council on Science and Technology.

[13] NSERC. 2009. *Strategy for Partnerships and Innovation*. p. 9. Retrieved June 2010 from: http://www.nsercpartnerships.ca/_docs/SPI_e.pdf

[14] NSERC Departmental Performance Report for the period ending March 31, 2009. Retrieved in Jan. 2010 from: http://www.nserc-crsng.gc.ca/_doc/Reports-Rapports/NSERC_Performance_Report_2009_eng.pdf

Question 4.1.1: To what extent have industrial partners gained knowledge and technology as a result of collaborations with university researchers?

In order for industrial partners to gain knowledge and technology as part of their collaborations with university researchers, the research results need to be transferred to the partner organizations. This is clearly the case for almost all CRD projects: only 2% of industrial survey respondents reported that the research results had not been transferred from the researchers to their organization (Table IV). The successful transfer of knowledge occurs mainly through direct interaction (formal or informal) with researchers, as well as through reports (internal and formal publications); these are also the key processes reported by industrial partners in the grant files. Interestingly, almost 20% of partner organizations indicated that hiring of HQP who had participated in the project was a means they had used to transfer the research results to their organization.

Table IV Process used to transfer research results to industrial partner(s)

Answer	%
Informal discussions and correspondence	79%
Reports that were used internally	76%
Formal publications (e.g., journal articles, conference papers/presentations)	63%
Direct involvement of organization in the project	54%
Hiring of HQP who participated in the project	19%
Other	11%
The research results were not transferred	2%
Total (n = 304)	

Note: Respondents could select more than one answer
Source: Web survey - industrial partners (funded)

Differences in the processes used to transfer results were examined by RPP sector, grant size and partner size; only the first variables were found to be of interest. Indeed, industrial partners in the Food and Bio-Industries sector were less likely to be directly involved in the project (38%) than partners in the Environment and Natural Resources (52%) or ICM (65%) sectors. Moreover, knowledge transfer through the hiring of HQP appeared to be more common in the ICM sector (24%) than in the Environment and Natural Resources (18%) or Food and Bio-Industries (13%) sectors. In terms of grant size, the use of informal discussion and correspondence decreased as the grant size increased (from 87% for small grants to 75% for large grants), whereas the use of formal publications increased with grant size (from 56% for small grants to 64% and 65% for medium and large grants respectively).

Other examples of the ways in which research results are transferred to the partners include: a members-only research portal available through the industrial partner's website (the industrial partner was an industry association); an international conference pertaining to the main research area of CRD projects organized in part by the academic researcher; direct and iterative involvement of industrial partners at each step of the optimization of the research results that required continuous discussion and communications between the scientists at each organization; and technology transfer, in the form of the algorithms and/or models developed as part of the project into software used or developed by the industrial partner.

The transfer of research results has increased the knowledge base of the partner organizations, with 92% of industrial partners indicating that they gained new knowledge through the project (based on grant file data). In fact, the increased knowledge base of the organization was the most highly rated impact of the CRD project, as reported by industrial partners (Figure 4, under Question 4.1.2). In the case of industry partners that are associations or part of industry associations, knowledge is typically disseminated among the members of the associations, as in the case of the research portal available on the partner's website.

Knowledge transfer is also indicated by the fact that industrial partners co-authored publications with university researchers—almost 50% of partners co-authored papers/presentations with the university researcher. However, it is difficult to assess how reliable and significant this finding is, as additional papers may have been published since the end of the CRD grant (and since the submission of the final research reports). It would also be interesting to compare the citations to papers co-authored with the industrial partners to those published by the researchers alone (i.e., through a bibliometric analysis). This type of bibliometric analysis would also allow for the comparison of publication impact compared to other NSERC programs, or other programs that support university-industry collaboration.

Finding 9: CRD project research results are consistently and effectively transferred to industry partners, leading to an increased knowledge base among the vast majority of partner organizations (>90%).

Question 4.1.2: How have industrial partners used, and benefited from, university research results?

Figure 4 shows how industrial partners used the results of CRD projects. Some 60% of partners reported tangible impacts on products and services, and 53% reported impacts on processes. Impacts on products and services were more often reported by partners who had received a large grant, while SMEs more often reported tangible impacts on their products and services than did large organizations. Only grant size seemed to have an impact on processes: the proportion of respondents who indicated this type of impact increased with the size of the grant.

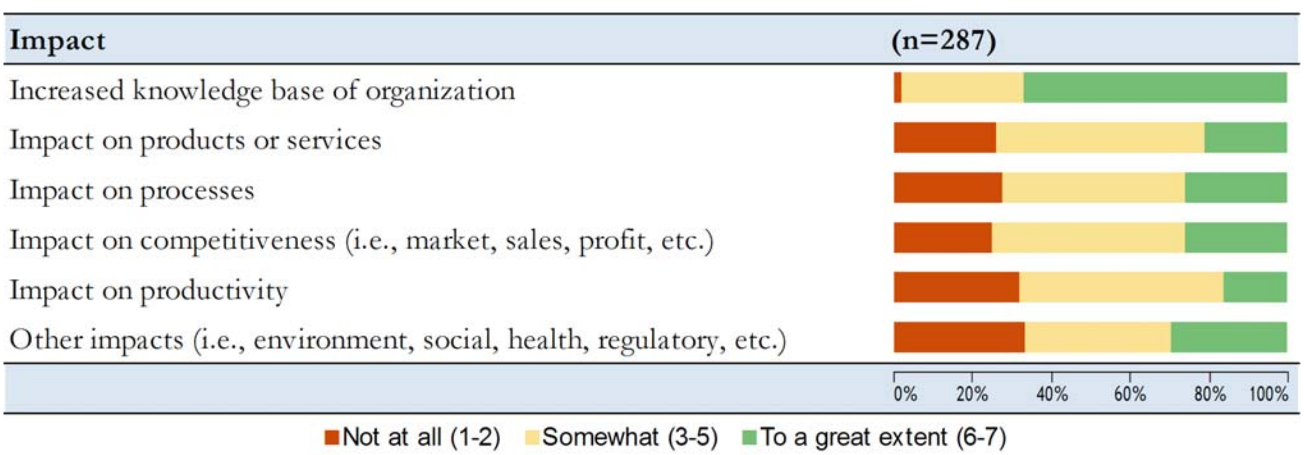

Figure 4 Impacts stemming from the use of research results
Source: Web survey - industrial partners (funded)

Of the web survey respondents who indicated that impacts had occurred with regard to products and services, most specified that these impacts had been new/significantly improved products (22% of 287 CRD projects reported in the survey), an increased range of products or services (18%), or new/significantly improved services (13%); one or more of these specific impacts was seen in 38% of all CRD projects.

The specific impacts identified by survey respondents who had indicated the occurrence of impacts on processes are shown in Table V; one or more of the four specific impacts listed in this table was seen in 34% of all CRD projects. The CRD projects resulted in significantly improved processes in 18% of cases, as well as new or significantly improved production processes for products and services in 15% of cases. The impacts on processes were associated with reduced costs, material or energy per unit of output in 15% of CRD projects, which can be inferred as improved productivity (see also Question 4.2).

Table V Impacts on processes stemming from the use of research results

Answer	%
Significantly improved an existing process	18%
New or significantly improved production process for products or services	15%
Reduced cost / materials / energy per unit of output	14%
Other	11%
New or significantly improved delivery / distribution process for products or services	4%
Total (n = 287)	

Note: Respondents could select more than one answer. Percentages are calculated based on 287 CRD projects reported in the survey.
Source: Web survey - industrial partners (funded)

In some cases, the results were beneficial not in terms of immediate improvements, but in helping make better decisions regarding the development or implementation of new processes, based on feasibility but also on costs. For example, in one of the case studies in the Food and Bio-Industries sector, the research results now allow for the characterization and selection of optimal crop types, and producers also possess standardized extraction and production techniques for the oil and powder forms of the crop that ensure maximum bioactive content within these products. It is expected that once production and harvesting techniques are sufficiently advanced, the techniques and processes developed as part of the CRD projects will enable Canadian producers to ship a high-quality product around the world.

Depending on the source of data (follow-up telephone surveys; web surveys), there is evidence that setbacks occurred in approximately one-quarter to one-half of CRD projects. Setbacks included lack of personnel with required skills and training, lack of interested personnel (“champions”) to drive the use of the research results, lack of R&D capacity/resources, or lack of compatibility with existing products, services or processes. Importantly, survey data show that industrial partners sometimes overcome these hitches and report impacts on products, services and processes despite the difficulties encountered: 15% and 10% for processes and products/services had very tangible impacts (rated 6 or 7), respectively, compared to 27% and 23% for those who do not report any difficulties.

Finding 10: Industrial partners use research results to improve and/or develop specific new products, services and processes in over one third of CRD projects.

Question 4.1.3: How do industrial partners benefit from the collaborations with academic researchers beyond the direct use of research results?

Collaborative R&D projects may benefit industrial partners in ways not related to the acquisition of new knowledge or through the direct use and application of research results. Overall benefits with regard to competitiveness, productivity and internal R&D activities are discussed in the following section, but other types of organizational benefits are described here. The benefits are less the result of the technical outcomes achieved by CRD projects and more the opportunities, linkages, cultural shifts and other value-added elements for the industrial partner organizations that are associated with the CRD projects. Note that the proportion of industrial partners who report these impacts fluctuates based on the data source (e.g., 2000 and 2002 follow-up surveys, web surveys), but this may be due to data collection procedures (i.e., phrasing and wording of questions, prompting by interviewers in telephone surveys) and so comparisons between these data sources should be approached with care.

In the web surveys, over 50% of industrial partners indicated that the CRD project had an impact on their organization's relationship building/networking (Table VI); respondents in the follow-up surveys also indicated that the CRD program provided the benefit of enhanced/encouraged collaboration and new links. The role of the CRD project in fostering collaboration and long-term partnerships is discussed further in Section 4.4. Other types of organizational impacts include the establishment or maintenance of a culture of innovation within the organization, increased access to HQP and learning about the benefits of academic R&D (Table VI).

> *"The CRD project provided a sounder, more rigorous approach than what can be achieved without access to the university facilities and staff." – Industrial partner*

Interestingly, icreased access to HQP had previously emerged as one of the key factors in the decision to participate in a CRD project for some partners (see Section 3.1). The finding of the web survey is corroborated by findings from both follow-up surveys, in which a similar proportion (20–30%) of industrial partners identified access to HQP as a benefit from participating in the CRD program.

> *"Generating qualified and capable people who can come out of these institutions and go into industry and be contributing members of the field is important. That pipeline of people has to continue and has to be supported." – Industrial partner*

Table VI Impacts beyond the direct use of research results

Answer	%
Relationship building / networking	52%
Established new / maintained existing culture of innovation	40%
Increased access to highly qualified personnel	33%
Learned about the benefits of academic R&D	30%
Increased access to facilities or equipment	25%
Total (n = 296)	

Note: Respondents could select more than one answer.
Source: Web survey - industrial partners (funded)

Increased visibility or reputation of the partner organization through their participation in the CRD project (a benefit reported by small number of industrial partners in the 2000 follow-up survey) can enhance relationship building, networking and recruitment benefits of the CRD projects. In one of the case studies, the academic researchers played a central role in the organization of an international conference on the CRD project's main topic, leading to increased international visibility of the Canadian community (both industrial partners and academic researchers) in this field. Moreover, the conference also led to the development of collaborations between Canadian and European/Asian researchers in this field, and an internship in Germany for one of the project HQPs.

> *"We have increased the visibility of our R&D organisation to the University. This is very valuable to us for recruiting new scientists."– Industrial partner*

Finding 11: **The benefits of increased opportunities for networking and access to HQP through CRD projects provide significant value added for industrial partners; access to HPQ, in particular, can act as a driver of industry participation in the CRD program.**

Question 4.2: To what extent has the CRD program increased the following for industrial partners: competitiveness, productivity, and investment in R&D?

Web survey data provide evidence that 54% of industrial partners increased their competitiveness and 45% their productivity in a tangible manner (i.e., rated 4 or higher out of 7) due to their participation in CRD projects. Impacts on competitiveness were more often reported by partners who participated in CRD projects that had received a large grant as opposed to a small or a medium grant. Conversely, SMEs more often observed these impacts (i.e., on competitiveness) than did large organizations.

Industrial partners were asked to indicate the specific ways in which their competitiveness had benefited from the CRD project (Table VII; respondents could select more than one answer). Almost one-quarter of CRD projects helped industrial partners keep up with their competitors, whereas other common benefits include increased market visibility and meeting the requirements of existing clients. Approximately 10% saw impacts on their bottom line or on their sales, including increased profitability, maintenance of their profit margin, and expansion to new markets. Overall, 43% of respondents indicated that one or more of the specific impacts listed in Table VII has been observed within their organization. Note that findings on improvements and/or development of new products and services, which led to an increased range of products of services in 18% of CRD projects (see Question 4.1.2, above), should also be considered as having contributed to market impacts for industrial partners.

Table VII Impacts on industrial partner organizations' competitiveness

Answer	%
Allowed the organization to keep up with its competitors	24%
Increased market visibility	17%
Met requirements of existing clients	16%
Increased profitability	11%
Allowed expansion to new markets	11%
Allowed the organization to maintain its profit margins	10%
Other	8%
Increased sales	8%
Increased market share	6%
Allowed the organization to expand	6%
Total (n = 287)	

Note: Respondents could select more than one answer. Percentages are calculated based on 287 CRD projects reported in the survey.
Source: Web survey - industrial partners (funded)

In terms of productivity, it was most common for industrial partners to report improvements at the business line/unit level (15% of CRD projects), followed by the facility/plant level (7%), but rarely at the level of the organization as a whole (1%). Note that impacts on processes—e.g., the fact that 14% of CRD projects led to reduced costs, material or energy per unit of output—can be inferred as having helped improve productivity (Table V). Examples were provided in which the CRD projects were said to have helped increase the efficiency of the development of new products, reduced the time required for certain tasks, and freed up staff to focus on different tasks. In some cases, productivity was seen to be improved for the customers/clients of the partners, or for the members of the industry association that participated in the CRD project.

Despite the vast amount of qualitative evidence on the economic impacts of the CRD program, the quantification of these impacts has proven elusive. In one case, for example, significant improvements to the industrial partner's main software product (in terms of speed and functionality) has allowed it to remain competitive and continue to dominate commercial/proprietary segment of the market; however, changes in profit and overall market share are difficult to measure, as the improvements affect an established package rather than new products with easily tracked sales figures, and because of the availability of competitive products that are freely available on the market.

In another case study (in the Food and Bio-Industries sector), the most frequently cited positive impacts of the project on animal feed include reduction of feed production costs, of Salmonella contamination and of the need for in-feed medication. Thus, the main economic impact has been cost-effectiveness across the industry that is represented by the industrial partner (an industry association), as producers can save from five to fifteen dollars per animal on feed costs compared to conventional systems, although other related health and environmental impacts should not be overlooked (see Question 4.2.1).

In the natural resources sectors, the contribution and impacts of CRD research results on discovery and exploration, while acknowledged, are difficult to measure because exploration is only one part of a large integrated operation that includes the extraction, transformation, and sale of the natural resources.

In addition, when knowledge or processes are shared across multiple industrial partners or via an industry association, measuring these impacts becomes increasingly difficult. Nonetheless, one of the industrial partners (an industry association) is currently conducting a study of the economic impact of a new production process that has been directly informed by the CRD grant (i.e., the techniques and processes developed as part of the project are now used commercially, three small production companies have been formed, one of which has products already on the market). This and other examples from the case studies suggest that industry associations/consortia may have a multiplying effect across their member organizations with regard to competitiveness and productivity impacts of CRD projects.

Finding 12: Impacts on competitiveness and productivity are perceived to occur in up to roughly 20% to 40% of CRD projects but are difficult to quantify. These impacts are more likely to be multiplied across several firms when the industrial partner(s) include industry associations or consortia.

R&D investments

More than 50% of industrial partners claimed in the web survey that the CRD program had tangible impacts on their organization's R&D activities (rather than on their management or investment), such as carrying out collaborative R&D, the nature of research topics and the methods employed (Figure 5). In contrast, changes in internal R&D budgets, management of R&D, number of R&D staff and plans to expand or establish a new research facility were less commonly reported. Still, changes in R&D budget and management were observed by more than one-third of respondents, and close to 20% said changes had occurred in the number of R&D staff and plans to expand their research facilities.

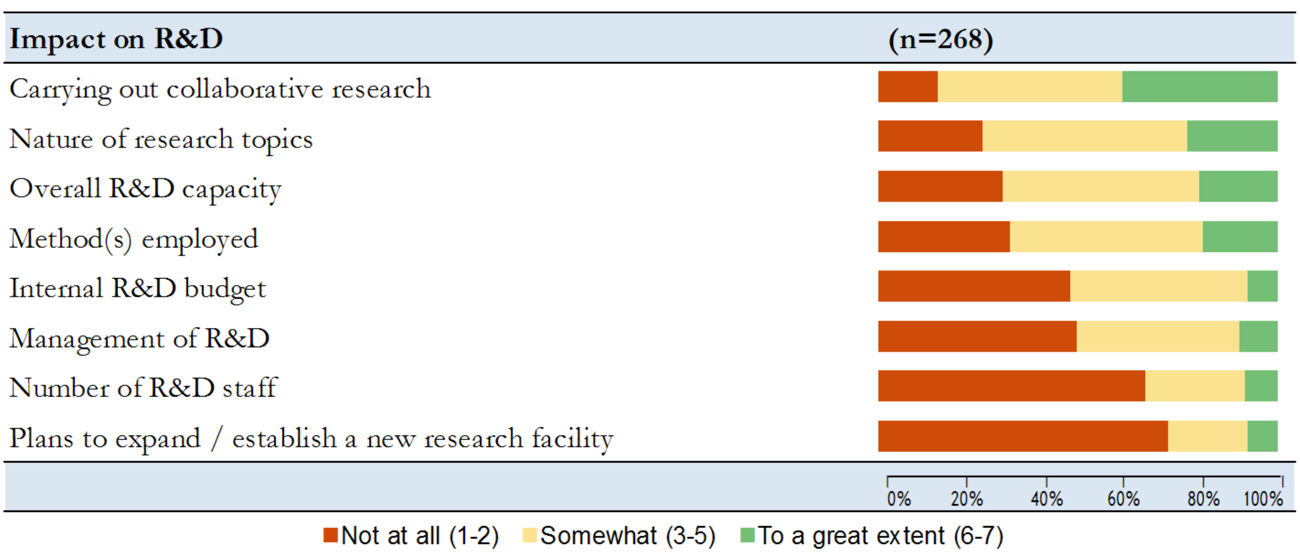

Figure 5 Impacts on industrial partner organizations internal R&D
Source: Web survey - industrial partners (funded)

Changes in the number of R&D staff were more often seen with large grants than with small or medium-sized grants, but this might simply be due to the fact that large grants support a larger research undertaking, prompting organizations to allocate additional human resources to their R&D department to help support this undertaking. More importantly, partner size was found to be associated with large effects created by CRD grants on the following aspects of internal R&D:

- Small organizations more often reported impacts on their internal R&D budget than did medium-sized or large industrial partners. This is likely due to the fact that their internal R&D budget was small to begin with.
- Changes in the management of R&D were more often seen in SMEs than in large organizations.
- Similarly, changes in the number of R&D staff were associated with partner size in the sense that impacts were more often reported in SMEs than in large organizations.

Finding 13: Impacts of CRD grants on internal R&D are greater for SMEs than for large organizations.

Question 4.2.1: Have there been additional economic, social or environmental benefits?

The CRD program is expected to contribute to benefiting the Canadian industry and economy. However, these outcomes are not usually measured at the program level because of attribution issues. Nonetheless, qualitative data were collected to provide evidence and examples of additional economic, social or environmental benefits of the CRD program. For example, at least 10% of CRD grants helped industrial partners achieve one or more of the following impacts: meet or improve response to regulatory requirements, reduce environmental damage or contribute to a policy, regulation or standard (data not shown). This evaluation also conducted an economic impact analysis, which aimed to estimate the CRD program's contribution to the Canadian economy (i.e., the Canadian gross domestic product [GDP]). This economic impact analysis helps support anecdotal evidence of economic benefits.

> *"For 15 years, our team received various grants, but the most important have been the CRD grants. In total, we obtained $1.5 million per year, for a total of over $20 million. Two industrial partners commercialized our results, with close to 400 employees. 90% of revenues are from exports. Now, each year, the employees and two companies together pay more than $20 million in taxes. The CRD investment in this research has been exceptionally profitable. These impacts would never have been possible without the CRD program."[15] – Academic researcher*

As part of the economic impact analysis, the contribution of the CRD grant program to the Canadian economy was measured from two distinct perspectives: the analysis first provided an assessment of the static impacts of the program, followed by an estimate of the dynamic impacts (see Methods). The gross static impact (GSI) of the CRD program attempts to measure the direct, indirect and induced impacts on the GDP of expenditures associated with the realization of the program. This approach treats the program as consumption: it demonstrates to what extent CRD dollars spent on consumption generated economic activities and jobs. The results show that the $255 million of 2006 constant dollars spent by

[15] « *Durant 15 ans, notre équipe a reçu diverses subventions en tous genres, les plus importantes ont été celles du RDC. Au total, nous avons obtenu 1.5M$ par an, ce qui totalise plus de 20M$. Deux partenaires industriels commercialisent nos résultats, avec près de 400 employés. Les revenus sont à 90% en exportation. Maintenant, à chaque année, les employés et les deux compagnies paient ensemble en impôts au delà de 20M$. L'investissement RDC dans cette recherche a été exceptionnellement rentable. Ces retombées n'auraient jamais été possibles sans le programme RDC.* »

the NSERC on the CRD program during the evaluation period generated almost $204 million of additional value added,[16] i.e., an increase of GDP in the rest of the Canadian economy. Since the CRD program supported collaborative projects with industrial partners and leveraged $222 million in cash contributions from these partners, the overall gross static impact of the CRD program is $377 million when both NSERC's and the partner's expenditures are included.

However, one has to bear in mind that the NSERC portion of the program is subsidized. This implies that if the public funds had not been spent on the CRD program, these funds would have been used for other projects that might have similar, larger or smaller GSI. Thus, viewed from the static perspective, when the subsidized NSERC portion of direct, indirect and induced impacts is deducted from the GSI, the resulting net static impact (NSI) falls substantially. Moreover, it is possible that the NSI of the CRD program could be negative if the amount of income that students forego by continuing their education rather than working is deducted from the GSI. In other words, the NSI depends on the way the foregone student's income is treated: whereas the NSI is slightly negative (-$4 million) when the foregone income is deducted from the GSI, it is clearly positive ($179 million) if the foregone income is considered as an investment rather than consumption.

There is a strong argument in favour of considering that students pursuing further education are making an investment: the income they forego during their studies reduces their immediate spending but likely increases their expenditures in the long run. This is because the supplementary education increases their competencies and is reflected in higher earnings that reward the increased productivity of their human capital. In fact, the analysis of dynamic impacts of the program (discussed below) demonstrates the way in which the increase in human capital through student training is a major contribution to the future increase in GDP. Thus, the estimate of a positive NSI of $179 million appears more realistic and plausible, especially for comparisons of the CRD program with other purely consumption-oriented publically subsidized programs and events. As this discussion suggests, the adjustments needed to estimate the NSI are necessarily approximations dependent on the logic of underlying assumptions and imperfect information available for their estimation.[17]

The investment character of the CRD program, the objectives of the program, and its contribution to the Canadian economy may conceptually be evaluated more realistically by estimating the program's dynamic impact: even though the underlying concepts for the assessment of dynamic impacts (and

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[16] The fact that the total impact on the GDP is inferior to the total cost of the program is explained by the portion of expenditures that are spent on imported goods and services, taxes and savings. The estimation of effects is based on Statistics Canada's assumption that 0.75% of earned income is spent. The low saving rate of Canadian households in the last 10 years suggest that perhaps a higher percentage would be more realistic. If such is the case, the estimated induced impacts would be proportionally higher.

[17] The fact that, in the calculation of the NSI, it is considered consumption rather than investment demonstrates a major weakness in the existing national accounting that considers R&D in the academic sector to be a cost rather than an investment. A revision of national accounting is being studied (see Siddiqi, Y. and Salem, M. *Treating Research and Development as Capital Expenditure in the Canadian SNA." System of National Accounts*. Statistics Canada, 2006). Moreover, as long as the estimated static impacts continue to be used for comparisons with alternative spending for programs and projects, this should also be a useful reminder of the fact that in times of full employment (as the Canadian economy experienced for a large part of the 1998–2007 period), an increase in public expenditures on some programs and projects means less spending for alternative uses.

especially their measurement) may be subject to debate,[18] the framework of the assessment of dynamic impacts is more appropriate for the CRD program than that of static impacts. There is no denying, however, that the measurement problems are important and that the results depend on the parameters (and thus, in many cases, on the assumptions made) used in the estimation. In the present economic impact analysis, attempts were made to estimate dynamic impacts of the CRD program using both a top-down and bottom-up approach (see Methods in Section A.2.5). However, as the proposed bottom-up estimation depended crucially on the availability of data, the data limitations encountered (see Section 1.6) were such that this estimation was simply not possible and only the top-down analysis could be completed.[19]

To alleviate as much as possible the effect of uncertainties on the top-down analysis, the analysis used a range of estimates: the lower boundary is more conservative and the upper boundary is less so. Interestingly, even the very conservative lower boundary of the estimated dynamic impact of the CRD program (i.e., $326 million) suggests a positive return on investment of NSERC's CRD program. This represents an annual return of about 6% percent, almost double the yield that would be obtained if the program's monies were invested in average real return long-term bonds.[20] From another angle, the lower boundary estimate suggests that each NSERC dollar spent on CRD grants generated an impact of at least 1.28 dollars on GDP in the business sector. The upper estimate—likely overly optimistic—suggests a return of about 4 dollars for each NSERC dollar spent on CRD research projects. Considering the inevitable uncertainty as to the actual value of parameters used to estimate the upper and lower boundaries of the dynamic impact, the average return of about $2.7 to each dollar invested in the CRD program seems within the realm of realistic possibilities.

Finding 14: The economic impact analysis of the CRD program indicates a positive return on investment on the Canadian GDP, particularly if the increased human capital resulting from the training of HQP is considered.

[18] See Lipsey, R.G. and Carlaw, K., (1998). *A Structuralist Assessment of Technology Policies- Taking Schumpeter Seriously on Policy*, Industry Canada, Working paper no. 25.

[19] Since the two methods proposed for the bottom-up approach are being increasingly used to analyze data in the statistical agencies, including Statistics Canada (e.g., using data collected in their Surveys of Innovation), it would be useful to attempt in the future to: (1) specify data requirements from CRD participants so as to enable econometric evaluations; (2) harmonize them with data collected in Statistics Canada's Surveys of Innovation; and (3) ensure access to Statistics Canada results to provide the control/counterfactual information, which is indispensable for the meaningful evaluation of any program.

[20] Considering the average length of CRD project funding to be three years and the opportunity cost of the funds to be 3.04, (the average real return benchmark bond yield [Statistics Canada, CANSIM series: v 3905]), NSERC's investment of $255 million in long-term real return bonds would have returned $279 million (2006 constant dollars), less than $302 million, the lower boundary of the estimated dynamic impact of NSERC-CRD program estimated in Table X. Like the note in an interesting paper by T.A. Brzustowski (Innovation = Invention + Commercialization: A Systems Perspective, *Optimum on Line, the Journal of Public Sector Management*, vol. 36, Issue 3, September 2006), this is a very crude attempt to figure out the return on investment of public funds spent on academic R&D, but it suggests that the money on the CRD program has been well spent.

4.2 Question 5: Impact on academic researchers

As key beneficiaries of the CRD grant program, academic researchers are expected to generate and derive a variety of impacts from their participation in the program. Most notably, an intermediate outcome of the CRD program is to enhance the research and teaching of university researchers as a result of their collaboration with industry, leading to an improved reputation for quality and expertise, as well as to the creation and dissemination of the new knowledge.

Question 5: What has been the impact of the CRD program on university researchers?

A very high level of achievement of project outcomes is consistently reported by the majority of academic researchers: on scale of 1 to 7 (where 1 means that the objectives were not at all achieved and 7 means that the objectives were achieved to a great extent), academic researchers give an average rating of 6.1 or 6.4, depending on the data source (research reports filed by researchers and web surveys, respectively). This is only slightly higher than the average rating of 5.9 for industrial partners.

The types of objectives pursued by CRD projects and the extent to which each type was achieved was examined in detail via the web surveys. An overview of the findings is presented in Figure 6; the grey portion of the bar—which represents the "Not applicable / Don't know" and blank responses—indicates that certain objectives were more frequently pursued by academic researchers (i.e., the grey portion is smaller), in particular the objectives to increase the fundamental knowledge base with transfer of knowledge to industrial partners and to produce a result that can be used by industry. Far fewer attempted to inform or contribute to policy or regulations (i.e., the grey portion is larger).

Using web survey data, the types of objectives that were pursued was found to vary according to several factors, such as the RPP sector in which the CRD grant was administered, the size of the grant, and the number of partners that participated on the project. The associations that were observed are listed below.

RPP Sector

- Projects in the Food and Bio-Industries more often aimed to "increase fundamental knowledge base, leading to transfer of knowledge to other academic researchers" than the two other sectors.
- The Environment and Natural Resources and ICM sectors more often sought to "produce a result that can be used by industry", "provide industrially-relevant training opportunities for HQP" and "develop or improve process/technology" than the Food and Bio-Industries sector.
- The Environment and Natural Resources sector more often sought to "inform or contribute to policy or regulations" than the two other sectors.

Grant size

- The proportion of projects that aimed to "produce a result that can be used by industry", "provide industrially-relevant training opportunities for HQP", "develop or improve process/technology" and "increase networking and build collaborative relationships with project partners" increased in association with grant size. This is not surprising, as large grants have the resources to pursue multiple and/or longer-term goals.
- Conversely, small grants more often sought to "increase fundamental knowledge base, leading to transfer of knowledge to other academic researchers" than medium and large CRD grants.

Number of partners

- Projects that involved two or more partners aimed more frequently to "increase fundamental knowledge base, leading to transfer of knowledge to industrial partner(s)", "produce a result that can be used by industry", "increase networking and build collaborative relationships with project partners" and "inform or contribute to policy or regulations" than did projects with a single partner.
- A higher proportion of projects with three or more partners sought to "develop or improve process/technology", whereas a smaller proportion of these projects sought to "develop or improve methodology/model" than did projects with one or two partners.

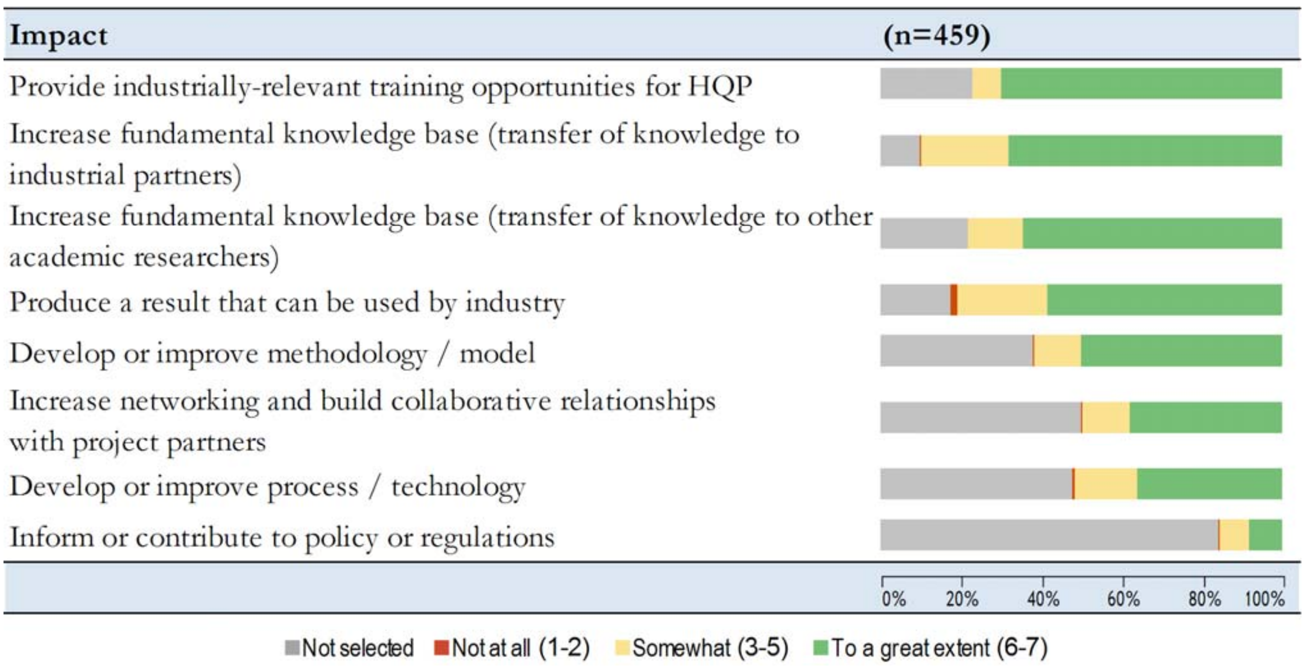

Figure 6 Types of objectives pursued and extent to which they were achieved

Source: Web survey - academic researchers (funded)

Figure 6 also indicates the extent to which each of the objectives were achieved, listing the impacts from top to bottom starting with the impact that was most frequently achieved to a great extent; for example, "providing industrially-relevant training opportunities for HQP" was achieved to a great extent by the largest proportion of academic researchers. Similar to what was observed for impacts reported by industrial partners (Figure 4), increasing the knowledge base of industrial partners was achieved to a great extent in a majority of CRD projects, whereas more technical impacts (i.e., developing methods, models, processes, technology, etc.) occurred less frequently. Several factors were found to contribute to meeting objectives (Table VIII), of which the availability of funds to conduct research, good working relationships with industrial partners and participation of students were cited by more than 90% of academic researchers in the web surveys. These findings are somewhat different from those in the two-year follow-up surveys, which indicate that academic researchers formerly placed less relative importance on having access to funding and on the involvement of students when identifying factors that contributed to the achievements of the partnership.

Table VIII Factors that contributed to the achievement of objectives

Answer	%
Availability of funding to conduct research	91%
Good working relationship with partner(s)	90%
Participation of students	90%
Interest and involvement of industry partner(s)	79%
Ability of industry partner(s) to make contributions	76%
Existence of pre-established relationships	69%
University team and industry partner(s) had shared expectations	69%
Access to equipment and facilities	59%
Expertise of industry partner(s)	55%
Type of project selected for CRD grant	54%
Management of intellectual property	18%
Other	5%
Total (n = 458)	

Note: Respondents could select more than one answer.
Source: Web survey - academic researchers (funded)

A closer examination of web survey responses indicate that the main factors which contributed to the achievement of CRD project objectives varied according to RPP sector, grant size and number of partners, as follows:

RPP Sector

- The "interest and involvement of industry partner(s)" and "expertise of industry partner(s)" more often contributed to the achievements of projects in the Environment and Natural Resources and ICM sectors.
- The "ability of industry partner(s) to make contributions" was seen as a more important factor by respondents in the Environment and Natural Resources than in the two other sectors.
- "Access to equipment and facilities" was more important in the Food and Bio-Industries than in the Environment and Natural Resources sector, whereas it was least important for ICM projects.

Grant size

- Several factors that played a role in the achievement of objectives were more important in large grants than in small grants, particularly "interest and involvement of industry partner(s)", "ability of industry partner(s) to make contributions", "existence of pre-established relationships", "university team and industry partner(s) had shared expectations", "expertise of industry partner(s)" and "management of intellectual property".

Number of partners

- Several factors were more important contributors to the achievement of project objectives in projects that involved three or more partners compared to projects that involved one or two partners, such as "ability of industry partner(s) to make contributions", "existence of pre-established relationships", "university team and industry partner(s) had shared expectations" and "management of intellectual property". Interestingly, all of these factors involve communication and management of relationships between the partners.

These findings clearly show that partner contributions and involvement is seen to have an impact on the achievement of CRD project objectives. Only a small proportion of CRD projects had no direct involvement of industrial partners (6% based on web surveys and 15% based on file review), and the most frequent type of involvement was "consultation" and "discussions" between the university and partner teams (Table IX). In more than half of CRD projects, partners provided facilities and were directly involved in the research (although this proportion was found to be lower in the file review). In addition, partners sometimes received training from university personnel or co-supervised students' theses. These findings are very consistent with the responses of the partners themselves when asked how they participated in the project beyond the cash contribution (data not shown), as well as with examples provided in the case study interviews.

Table IX Involvement of industrial partners in CRD projects

Answer	%
Partners were available for consultation	90%
Partners discussed the project regularly with the university team	82%
Partners provided facilities / equipment	58%
Partners were involved in the research	56%
Partners received training from university personnel	27%
Partners co-supervised students' theses	18%
Partners were not directly involved in the project	6%
Other	3%
Total (n = 453)	

Note: Respondents could select more than one answer.
Source: Web survey - academic researchers (funded)

Partners in the Food and Bio-Industries sector are less involved in the CRD projects than partners from the other two sectors; this is observed for all types of involvement listed in Table IX. Approximately 10% of industrial partners in the Food and Bio-Industries sector are industry associations (particularly in the case of agricultural industries), compared to 3% for the ICM sector and 4% in the Environment and Natural Resources, which might help to explain this difference in involvement. Partner size appeared to play a role in the involvement of organizations: large partners more often provided facilities and regularly discussed the project with the university team than did small partners. Finally, projects that involved three or more organizations appeared to more often involve the training of partners from university personnel and the co-supervision of students' theses than projects with one or two partners. This is not surprising, as the participation of additional partners also increases the number of chances that these less frequent types of involvement will occur.

Setbacks were encountered in approximately 60% of CRD projects and were generally of a technical or scientific nature (40%), involved staffing issues (24%) or involved funding (13%). Evidence from web surveys suggests, however, that most problems are overcome, allowing for the successful completion of the research project. Examples of problems that resulted in a low achievement level include: lack of funding due to withdrawal of the industrial partner, delays in matching payments, issues with the nature of the project (e.g., too theoretical, research led in a different direction) and lack of support from the university with regard to paperwork or project management. Internal key informants confirmed that these more serious problems occur, albeit rarely. In the case studies, none of the problems that occurred were serious enough to prevent the achievement of the main technical objectives of the project; however, other issues that limited the use and impact of research results for industrial partners are discussed under Question 4.

Finding 15: Academic researchers report that funding, partner involvement, and participation of HQP are key to the achievement of CRD project objectives.

Finally, benefits for academic researchers are also indicated by the high proportion who have already participated in multiple CRD projects or who indicated the likelihood to apply for future CRD grants. Indeed, program data indicate that 30% of academic researchers have been involved in more than one CRD project during the period from 1998 to 2007, which is consistent with the results of the academic research web survey wherein more than 80% of respondents indicated they are likely to apply for another CRD grant (rating of 6 or 7, where 7 means "to a great extent"). These findings are also supported by the fact that approximately 45% of researchers reported having already obtained a CRD grant to fund subsequent collaborative R&D projects with industrial partners (data not shown).

The case studies also suggest that certain researchers, particularly those who have worked for a time outside of academia, are very keen to collaborate with industry and are "continuously looking for more partners." The granting history of these researchers who participated in the case studies also provides evidence of a sustained interest in working on collaborative R&D for most of the researchers, as indicated by a high number of grants that involve partnerships with industry, including other CRD grants, an NSERC Industrial Research Chair, MITACS (NCE) grants and research contracts with industry.

Question 5.1: To what extent have researchers created and disseminated new knowledge and technology to industrial partners and the research community?

As part of their CRD projects, a large proportion of academic researchers successfully increased the fundamental knowledge base (involving transfer to either or both their industrial partner and other academic researchers) and produced results that can be used by industry. The processes that were used to disseminate—and in some cases to protect—this new knowledge and other research results are examined here.

The main processes used to transfer research results to industrial partners included both informal discussions and correspondence, followed by reports and formal publications; these were used in more than 80% of CRD projects (Table X). In addition, direct involvement of partners was also common. Not surprisingly, these processes are similar to those reported by industrial partners (as presented in Section 4.1, see Table IV), although the academic researchers report slightly higher rates of transfer using each means. As noted in previous sections, the case studies also indicated that, in addition to the processes listed in Table IV, some academic researchers have actively used additional means of transferring research results to partners, including websites, conferences, in-house training and technology transfer.

Table X Process used to transfer research results to industrial partners

Answer	%
Informal discussions and correspondence	86%
Reports provided to the industrial partner(s)	84%
Formal publications (e.g., journal articles, conference papers / presentations)	82%
Direct involvement of industrial partner(s) in the project	62%
Other	11%
The research results were not transferred to the partner(s)	0%
Total (n = 455)	

Note: Respondents could select more than one answer.
Source: Web survey - academic researchers (funded)

New knowledge generated during the CRD projects often took the form of tangible results. Based on the grant files (FY2004–2007), these tangible results include improved processes (approx. 40% of CRD projects), new processes, prototypes/pilots and improved products (each approx. 30% of CRD projects), new products (approx. 17% of CRD projects) and contributions to policies or regulations (15% of CRD projects). These rates are slightly higher than those reported by industrial partners, suggesting that the research results were not always used and/or applied by the industrial partners, or perhaps that “use” is perceived differently by researchers and partners.

Academic researchers are also used to disseminating new knowledge among the research community through publications and other outputs, particularly through refereed journal articles and conference presentations. Research results produced as part of CRD projects were extensively disseminated through a variety of means, with an average of more than 18 publications per project (Table XI). These numbers are slightly higher than those reported in the grant files (average of 15 publications per project), which is to be expected since more time has elapsed since the end of the project, during which additional outputs can be prepared and disseminated. Note that to better assess the quality and impact of these publications—more particularly the peer-reviewed papers—it would be of interest to examine the citations received by these outputs though bibliometric analyses.

Not surprisingly, a strong association exists between the number of refereed journal articles, theses and conference presentations/posters and the size of the grant: small grants produced an average of 8 of these outputs per project, medium grants produced 13 per project, and large grants produced over 30 per project. No differences were seen in the output rates between RPP sectors.

Researchers have also sought to protect the intellectual property (IP) of research results: according to survey data, IP was protected in 25% of projects, mainly through patents (16% of projects), as well as through non-disclosure or confidentiality agreements (10% of projects). The nature of the research was such that IP protection was deemed "not appropriate" by academic researchers for approximately 60% of CRD projects, although it would have been appropriate for 11% of projects that were not protected (web survey data). IP protection was strongly associated with grant size, with almost half of large grants reporting some form of IP, compared to 9% of small grants. IP protection was also more frequent in the ICM and Food and Bio-Industries sectors than in the Environment and Natural Resources sector.

Table XI Number and type of publications from CRD project results

	% Projects	Mean output/ Project	Output
Conference presentations / posters	94%	7.9	3558
Refereed journal articles	90%	5.4	2420
Theses (subject directly related to CRD project)	89%	2.6	1156
Non-refereed journal articles	38%	1.4	652
Other (excluding patents / licences)	16%	0.9	397
Total		**18.2**	**8183**

Note: Respondents could select more than one answer
Source: Web survey - academic researchers (funded)

Patents were filed mainly in the US (42%) and Canada (31%), but also in Europe (20%) and Asia (3%); patents were issued in almost identical proportion. The total number of patents reported in the web surveys (277 filed and 135 issued) does not represent the total number of patents filed or issued for all CRD projects during the evaluation period because the survey does not encompass the entire population. Based on the grant files (FY2004–2007), 30 patents were filed and 15 patents were issued, on average, per 100 CRD projects (including projects that did not report any patenting activity).

Licensing was reported by academic researchers (web surveys) in 31% of projects for which IP was protected, or 8% of total CRD projects. This is slightly higher than the 6% rate observed in the grant file review. Similar to the findings on patenting activity, large grants more often led to licences than did small and medium grants. However, licensing activity was not associated with RPP sector. In addition, projects involving three or more partners had a higher rate of licensing activity than projects with one or two partners. A total of 30 licenses were reported in the grant files (FY2004–2007), whereas 45 licenses were reported by survey respondents (although there is certainly overlap between these two figures); half of the licences reported in the web surveys generated revenues. Reported revenues ranged from $760 to more than $1 million, with most being in the $100,000–$500,000 range.[21]

[21] While it should be stressed that these figures do not include all CRD projects completed during the evaluation period, it is worth noting that the total revenue generated to date from licensing of projects that were covered in the web survey is almost $2.4 million dollars and excludes the amount provided by one respondent, who stated that $3 billion had been generated from licensing a drug that was developed at least in part through a CRD project. However, these data have not been independently verified.

Web survey respondents indicated the creation of 26 spin-off companies, 18 of which are still active. Spin-off companies were more often the result of large CRD grants (compared to small or medium grants) and CRD projects that involved two or more partners; there was no association with RPP sector. Because the survey represents only one part of the program's participants, these numbers underestimate the total number of CRD-related spin-off companies created during the evaluation period.

Finding 16: Academic researchers created and widely disseminated new knowledge and technology, for an average of 18 publications (papers, conferences/posters and theses) per CRD project. At least 135 patents were issued as a result of the 460 CRD projects examined in the web survey.

Question 5.2: What impact has participation in the CRD program had on university researchers' research?

The CRD program, in supporting collaborative R&D between industrial partners and academic researchers, also aims to enhance the research performed by, and the reputation of, university researchers. Web survey findings on this question are summarized in Figure 7. Impacts were seen to a great extent in the form of "increased focus/specialization on research areas related to the CRD grant" (62%), followed by changes that "led to new research areas/projects not addressed by the CRD grant" (57%) and "increased opportunities for additional research funding" (54%). CRD projects also led to "increased focus on industrially relevant, applied research" and "new areas of fundamental, basic research" in just under 50% of cases. Because the grant files are compiled shortly after the end of the CRD grants, impacts on research were assessed slightly differently in the file review, which found that the CRD project had "opened up new opportunities for research beyond the original objectives" for over 80% of researchers, and "influenced direction to more industrially relevant topics" in at least 55% of cases. Examples abound that demonstrate how researchers are experiencing enhancement in their research activities and their reputation as researchers as a result of the CRD program.

> *"The CRD program from an academic point-of-view was probably the more productive of all of the work of my career. The ability to work with other academic and industrial colleagues and associated HQPs with no discipline barriers—focussing on the problem—can not be overstated. The results are still ongoing as the CRD fundamental results are being used in developing high-end models." – Academic researcher*

> *"This project was our introduction to a new field of research which is now our main activity."– Academic researcher*

> *"Established an industrial research chair and led to many other contracts."– Academic researcher*

> *"The CRD project helped develop a protocol for sustainable technology development. This created a new line of research, rarely undertaken in Canada. This led to large grants (provincial and federal)." – Academic researcher*

> *"Our work became known to other industrial and regulatory parties due to technology transfer at specialized meetings."– Academic researcher*

> *"Led to three other CRD projects and approximately six parallel projects funded by other sources."– Academic researcher*

> *"The CRD support was valuable as it effectively provided three years of operating funds for my new CFI project (CFI-IOF did not exist at that time)." – Academic researcher*

> *"Won the NSERC Synergy Award for Innovation." – Academic researcher*

Differences were observed in terms of research impacts across RPP sectors and depending on the doctoral degree year of the researcher (which can be used as an approximate indicator of the period over which they have been involved in research activities). Indeed, researchers in the ICM sector were more likely to see an "increased focus/specialization on research areas related to the CRD grant" than those in the two other sectors, whereas researchers in the Food and Bio-Industries were less likely to report an "increased focus on industrially relevant, applied research" than those in the two other sectors. As for the changes experienced by researchers with regard to the length of their research career, the most striking finding was "increased opportunities for additional research funding": researchers who obtained their PhD more recently reported greater impacts in this regard. This suggests that CRD projects help serve as a means for researchers to enhance their reputation and obtain further research funding. In contrast, more experienced researchers (i.e., who obtained their PhD prior to 1985) were less likely to report that the CRD project had "led to new research areas/projects not addressed by the CRD grant" or "increased focus on industrially relevant, applied research". This last finding may be related to the fact that these researchers are closer to retirement (or already retired) or simply have a more established research program and so are less likely to embark on new research areas or projects.

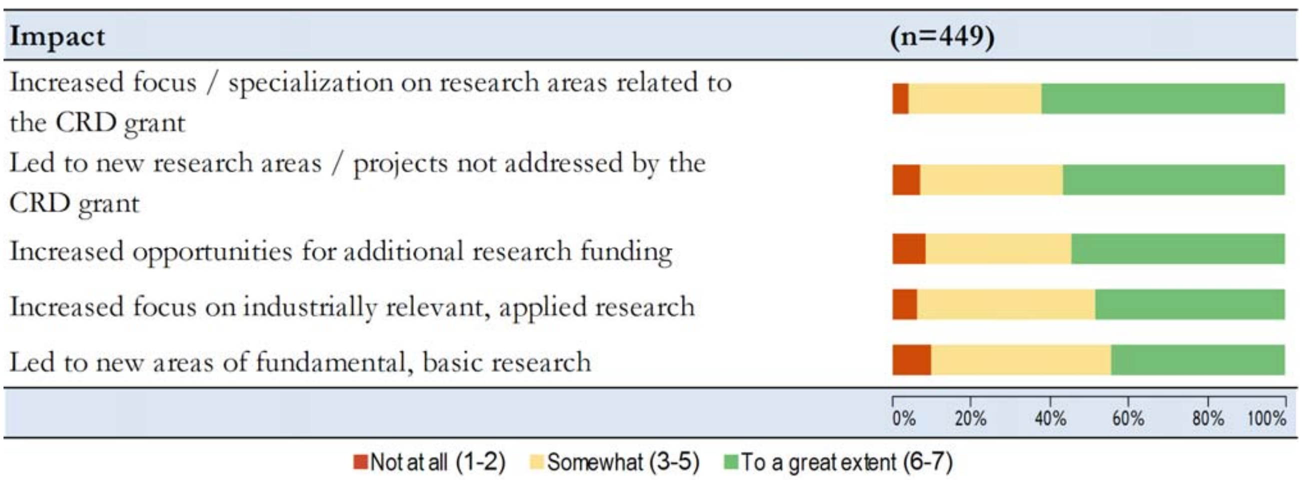

Figure 7 Impact on academic researchers' research
Source: Web survey - academic researchers (funded)

The number of other NSERC grants held by CRD-funded researchers can also be used as a proxy of the quality and expertise of these researchers; however, further work would be necessary to assess whether changes in funding can be linked to CRD funding. Of the 1,078 researchers that held CRD grants during the evaluation period, 95% held other NSERC grants during the 1998–2007 period, for an average of 4.4 other NSERC grants. Overall, 30% held at least one other CRD grant, and 65% held NSERC grants other than a CRD grant during the period. Of the other NSERC grants held over this period, the most frequently held were Individual Discovery Grants (2,627 grants), Research Tools and

Instruments – Category 1 Grants (886), Strategic Project Group Grants (368), Industrial Research Chairs (112),[22] Industrially Oriented Research Grants (106) and Idea to Innovation Grants (82).

Finding 17: The CRD program helped to shape and strengthen participating academic researchers' research and reputations and increased opportunities for researchers to obtain further research funds.

Question 5.3: What impact has participation in the CRD program had on university researchers' teaching?

The CRD project also influenced the teaching activities of almost 90% of academic researchers, feeding the content of the courses they teach, such as through the use real world examples (76%), providing new content for existing courses (62%) or, less frequently, leading to the creation of new courses (7%). In 28% of CRD projects, new equipment or material was obtained for teaching or training. Incidentally, these impacts were reported at similar rates in the file review.

Academic researchers who participated in the case studies explained how their CRD-funded research could also inform their teaching by providing new knowledge, tools and materials (in terms both of subject matter and applications). These are then used in the development of new courses, as well as in the provision of models and examples of applied problems and successes for existing courses. Interestingly, innovative projects, advertised in class as well as in the media, have also proven attractive to incoming graduate students and in a number of cases made it easier for the researcher to attract new students. Furthermore, HQP who go on to positions in academia can also draw on CRD projects to inform their teaching.

> *"Students who heard about the work in class came forward to express their interest and two were subsequently hired for later fieldwork on the project—both now work in industry." – Academic researcher*
>
> *"Following the completion of my master's, I have used this knowledge in my teaching and in my further research in this area. And since my appointment as a professor at [a university in Colombia], the Colombian community has also benefited through my transference of this experience and knowledge." – HQP*

Impacts on teaching naturally lead to a discussion of impacts on students and other HQP, which is the topic of the next section.

Finding 18: Academic researchers use the knowledge, tools and materials they acquired through the CRD project to enhance and inform their existing courses and, sometimes, to create new courses.

[22] During the early part of the evaluation period the CRD program was used to pay out the non-salary components of Industrial Research Chair program.

4.3 Question 6: Impact on HQP

Question 6: What has been the impact of the CRD program related to HQP?

CRD projects are now required to include the participation of students, who along with post-doctoral fellows, research associates and technicians, are grouped under the term "highly qualified personnel" (HQP).[23] The rationale behind this requirement is that the CRD program can contribute to the training of HQP with the skills needed by user organizations; as such, an intermediate outcome of the program is that HQP obtain employment in their field and require less training once employed.

To assess this, and to determine the industrial relevance of the environment and expertise to which the HQP are exposed, data were collected using the document and file review, web surveys and case studies; the last two methods collected data directly from HQP who have participated in CRD projects. In both cases, the HQP were identified and invited to participate by the academic researchers, which likely introduced a bias in terms of the types of HQP who completed the survey compared to the total population of HQP who participated in CRD projects (i.e., researchers may be less likely to have current contact information for undergraduate students or more likely to invite HQP who have become collaborators in the academic sector). However, data collected from HQP provide valuable examples of the benefits gained by this group through the CRD program.

Overall, an average of approximately 9 HQP per CRD grant is reported by academic researchers consistently across data sources (i.e., grant files and web surveys); this average total includes all CRD projects, even those who reported no HQP involvement. HQP were more often students (undergraduate or graduate) than post-doctoral fellows, research associates, technicians, or other[24] (Figure 8). HQP survey respondents most often participated in the CRD project as doctoral or master's students, which could indicate that undergraduate students are under-represented in data collected through this survey (as discussed in the previous paragraph).

Unsurprisingly, these data also reveal a strong association between the size of the grant and the number of HQP participating in the project: small grants involved fewer HQP (4.2, on average) than medium (7.6) or large grants (15.7). This difference is seen in terms of the average number of HQP per project for all types of HQP but especially influences the proportion of projects that involve doctoral students, post-doctoral fellows and research associates involved in the project. For example, only 30% of small CRD grants involve a post-doctoral fellow, as opposed to 71% of large CRD grants. This may be because smaller grants are not sufficient to support a post-doctoral fellow (in terms of time and/or salary), or that the scope of smaller research projects would not require the involvement of a post-doctoral fellow to manage the project. Further work would be required to test these hypotheses.

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[23] Student participation was not a formal requirement during the first years of the evaluation period but few projects operated without any students; for example, only 12% of projects (which were completed between 1998 and 2000) examined in the 2002 two-year follow-up survey did not involve any student participation.

[24] Based on web survey data "Other HQP" represented a very varied list of individuals. For example, they comprised academic colleagues/other faculty members (including some who received industrial training); visiting scientists; researchers and engineers from industrial partner organizations; part-time research assistants; summer students/interns; surgical fellows; and scientific consultants.

Differences in the number of HQP involved also appeared when the data were broken down by RPP sector: CRD projects in the ICM sector tend to involve more HQP (average of 9.3), particularly master's and doctoral students, than projects in the two other sectors (average of 8.4 for both). In contrast, a greater proportion of CRD projects in the Food and Bio-Industries and Environment and Natural Resources sectors involve technicians than projects in the ICM sector.

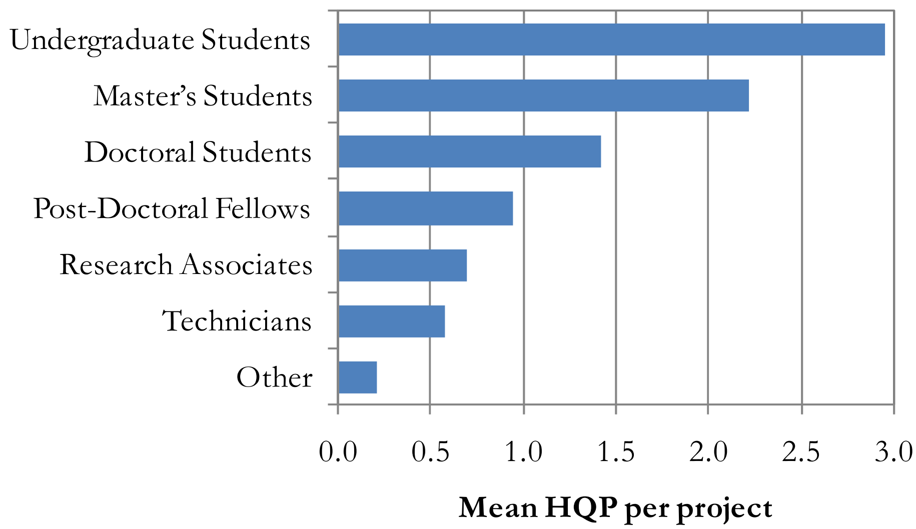

Figure 8 Number and type of HQP participants
Source: Web survey - academic researchers (funded)

Based on the file review, post-doctoral fellows, on average, spent the highest number of calendar years participating in CRD grants (1.9 years), followed by research associates and doctoral students (1.8), master's students (1.6), technicians (1.5), other (1.26) and undergraduate students (0.5). On average, other HQP received the highest percentage of their salary from CRD grants (26%), followed by research associates (24%), technicians (22%), post-doctoral fellows (18%), doctoral and master students (16.5% each) and undergraduate students (9%). In terms of HQP whose entire salary was supported by the CRD grant, master students were most often fully funded by the CRD grant (17%), followed by post-doctoral fellows (14%), doctoral students (11%), undergraduate students (10%), research associates (9%), other HQP (9%) and technicians (7%). Thus, the involvement of HQP in CRD projects varies in terms of time and resources, but these findings clearly indicate that CRD projects provide significant opportunities for benefits to be acquired by HQP.

Finding 19: An average of nine HQP participate per CRD project, many for at least one calendar year—this provides significant opportunities for HQP to contribute to and benefit from the program.

Question 6.1: To what extent have HQP conducted research in an industrially-relevant environment?

Through their participation in the CRD project, HQP have multiple types of interactions with industrial partners. These interactions primarily involved presenting research results to the project partner(s) and discussing the project directly with the partner(s) to obtain input (Table XII).

"Students worked in industrial laboratory on their M.Sc. and Ph.D. thesis. Industrial personnel co-supervised the students and served on the academic committees." – Industrial partner

Doctoral students were the type of HQP that interacted most frequently with industrial partners, as more than 90% had direct interaction with the partners. A greater proportion of master's and doctoral students more frequently presented research results to the partners than other types of HQP, whereas post-doctoral fellows and researcher associates more often indicated that they attended regular project meetings with the organizations involved in the CRD project. All types of HQP reported similar rates in terms of discussing the project directly with the partners and working in the facilities of the partner organizations. Based on the file review, HQP spent roughly 10% to 30% of their research time on the CRD project. This proportion was highest for post-doctoral fellows (29%), followed by research associates (20%), other HQP (18%), doctoral students and technicians (17% each), master students (16%) and undergraduate students (11%).

Table XII HQP interactions with industrial partners

Answer	%
I presented research results to the partner(s)	72%
I discussed the project directly with the partner(s) to obtain input	57%
I attended regular project meetings with the organization(s)	36%
I regularly worked in the facilities of partner organization(s)	28%
One or more partner(s) jointly supervised my thesis project	11%
I had limited interaction with the organization(s)	9%
I did not interact with the partner(s)	7%
Total (n = 130)	

Source: HQP web survey

The majority of HQP (72%) perceived that the environment in which they had conducted their research was relevant to industry (see Figure 9); industrial partners who went on to hire project HQP (76%) agreed that this was the case. In addition, 94% of academic researchers who completed the web survey indicated that HQP had been exposed to industrially relevant research projects through their participation in the CRD project. In the web surveys, a similar proportion of HQP types gave a high rating (6 or 7 on a scale of 1 to 7, where 7 means "to a great extent") to the statement "I conducted research in an industrially relevant environment", but those who have a low rating (1 or 2) were more likely to have participated in a CRD project as a graduate student than as a post-doctoral fellow or research associate. With regard to the type of interaction[25] and the extent to which the HQP perceived their research environment to have been industrially relevant, the web survey data show that the higher the interaction level, the higher the proportion of HQP who gave a high rating to the above statement.

[25] "Low interaction" included respondents who reported no or limited interaction with partners; "medium interaction" involved presenting results, attending meetings, and discussing the project with the partner; and "high interaction" involved working in the facilities of partner organizations and having a partner supervise the HQP's thesis project.

> *"This project allowed us, as members of an academic research lab, to interact with scientists from industrial labs. We got to see their processes and learn how they approach research problems. We were exposed to a lot of new instrumentation and methods. It was a really great learning experience… one you can't get from a traditional university environment." – HQP*
>
> *"I think the CRD program is [a] good chance for the graduate students to interact with industry and learn what is important in industry. I myself do a lot of collaborative research with industry. I still keep in touch with the industrial partners of the CRD project and have developed many new projects." – HQP*
>
> *"It allowed me to develop my technical and scientific skills relevant to my current employment with good exposure to the industrial environment and its needs, while being somewhat sheltered from large amounts of daily constraints that can occur in an industrial environment. I consider this working environment to have been extraordinarily conducive to my personal professional development. My participation in the project opened the door for me to my current employment with the former industrial partner. In summary, my participation in this project has had an extremely positive impact on my career." – HQP*

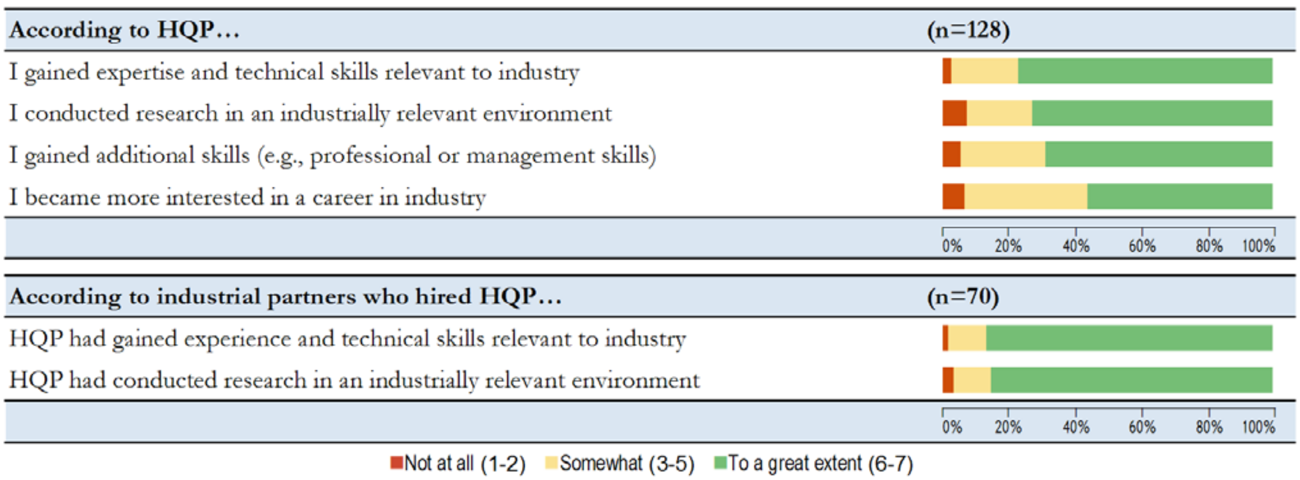

Figure 9 Perceptions of HQP and industrial partners on aspects relating to experience and skills through HQP participation in CRD projects

Source: Web survey of industrial partners (funded) and HQP

Finding 20: HQP conducted research and acquired skills in an industrially-relevant environment, particularly those that had a high degree of interaction with industrial partners.

Question 6.2: To what extent have HQP gained expertise and technical skills relevant to industry?

More than three-quarters of HQP report that they gained expertise and skills relevant to industry "to a great extent" through their participation in the CRD project (Figure 9). This is corroborated by more than 80% of industrial partners who hired HQP who report that HQP gained expertise and skills relevant to industry "to a great extent" through their participation in the CRD project (Figure 9). In addition, 68% of HQP indicated that they had gained additional skills (e.g., professional or management skills) through their CRD project experience. Note that the extent to which HQP agreed with the fact that they had gained various types of skills increased slightly in association with the level of interaction they had with the industrial partners.

In the web surveys, HQP (n = 111) were asked to provide details on the specific skills they acquired as a result of this experience. This resulted in a list of more than 230 skills, which varied from technical to professional, some of which were relatively trivial while others were clearly valuable (i.e., a skill was considered to be valuable when HQP indicated that it was essential or important with regard to their current job). The main types of skills and expertise they reported are summarized below.

- Research skills and experimental design, especially for applied/industrially relevant research;
- Analytical skills, statistics, dealing with datasets;
- Technical skills relevant to their field (e.g., lab techniques, modelling, sampling);
- Computer skills, including programming and design/use of advanced software;
- Communication and presentation skills (written and oral), including with a non-academic audience;
- Understanding of and experience dealing with policy/regulations relevant to their field;
- Project management skills, dealing with the logistics of lab/field work;
- Supervision, leaderships and teamwork skills; and
- Hands-on experience working with industrial partners.

The last—hands-on experience working with industrial partners—is the most unique skill conferred to HQP by the CRD program (as compared to purely academic graduate scholarships, for example). Examples given of industrially relevant skills are particularly interesting for this evaluation.

> *"I became familiar with some of the tools available in industrial settings, as well as some of the processes in place in such environments."*
>
> *"Close interaction with practicing specialists. Close acquaintance with the labour market in the industry."*
>
> *"The analysis of challenges associated with the transfer of research results from the laboratory scale to the industry scale."*[26]
>
> *"Skills both in terms of presenting and acquiring information to/from management and front-line developers."*

Finally, networking skills and contacts should not be overlooked, as evidence from the case studies suggests that these are particularly useful to HQP who go on to work in the field. Indeed,

> *"The networking that is involved in these types of projects is extremely useful. You work with industry and other departments and you meet people that you can continue to work with in the future... it has led to an interdisciplinary network of helpful academic and industry-based individuals."*

Finding 21: HQP acquired a varied range of skills and expertise from working on CRD projects, some of which are unique to collaborative R&D and contribute to their future work in the field.

Question 6.3: To what extent are HQP obtaining employment in their field?

Question 6.4: To what extent, and in what capacity, are industrial partners hiring HQP involved in CRD projects?

As shown in Figure 9, about half of HQP indicated that they had become more interested in a career in industry "to a great extent" as a result of their participation in a CRD project. Data from the academic researcher and HQP web surveys provides evidence of the extent to which HQP are obtaining

[26] *"L'analyse des contraintes quand il s'agit du transfert des acquis de la recherche de l'échelle du laboratoire à l'échelle de l'industrie."*

employment in their field, including within the industrial partner's organizations. Academic researchers reported on the employment status of HQP in the file review (i.e., shortly after the end of the grant) and in the web survey (up to 10 years after the end of the grant). The most notable difference between these sources was the number of HQP still in academic training, which was close to 40% in the file review and approximately 20% in the web survey. This difference is expected because HQP eventually complete their academic training and find employment. However, percentages of HQP employed in various sectors were very similar across data sources once the difference in number of HQP who were still in academic training at the time of reporting had been accounted for, so only web data are presented and discussed below.

Academic researchers indicated that almost half of HQP involved in their CRD project were offered jobs or contracts after their participation in the CRD project. According to academic researchers, HQP who are employed are hired primarily by the private sector (69%), followed by the academic sector (21%) and by government (10%). These rates did not vary in a notable fashion according to grant size or number of partners, although some differences were observed based on the RPP sector of the project in which the HQP was involved.

- HQP from projects in the Food and Bio-Industries sector were more often employed in academia (28% of employed HQP), than those who conducted research in the other two sectors.
- HQP from ICM (75% of employed HQP) and Environment and Natural Resources projects (69%) were primarily employed in the private sector. Less than half of HQP from Food and Bio-Industries projects were employed in the private sector.

Almost 80% of HQP who responded to the web survey indicated that they were employed full-time (14% were still in academic training); of these, 46% were primarily employed by a university, 34% in the private sector and 15% in government. Compared to the distribution of HQP as reported by academic researchers, this suggests a response bias in the survey respondents toward HQP currently employed in academia. However, depending on the RPP sector of the project in which the HQP was involved, similar patterns can be seen between the ways in which employment varied among HQP survey respondents and HQP, as reported by academic researchers.

- HQP from Food and Bio-Industries projects were more often employed in academia (61%) than HQP from ICM (47%) and HQP from Environment and Natural Resources projects (37%).
- HQP from Environment and Natural Resources projects were primarily employed in the private sector (41%), compared to 29% for ICM and 26% for Food and Bio-Industries.
- HQP from ICM and Environment and Natural Resources projects (17% and 18%) were more often employed in government than those from Food and Bio-Industries projects (9%).

HQP survey respondents who were employed in academia primarily held positions as researchers (38%) and faculty (31%), although a few worked as research associates and technicians. Over 60% of HQP survey respondents working in the private or government sectors were hired by an organization in an industry or area related to the CRD projects in which they were involved or by the industrial partner organization.

Indeed, when considering all HQP who have participated in CRD projects (including those still in academic training or pursing other activities), approximately 11% of HQP go on to be hired by the industrial partner. Within the subgroup of HQP who are employed full-time, 15% were hired by one of the industrial partners. Among HQP who work in industry, 20% were hired by an industrial partner. File review data indicates that industrial partners more often hired graduate students and technicians than other types of HQP, particularly undergraduate students.

Almost one-quarter of industrial partners who completed the web survey reported that their organization had hired one or more of the HQP involved in the CRD project. Respondents working for large organizations were slightly more likely to indicate that HQP had been hired, as were organizations in the ICM sector. As mentioned above, access to HQP can be a motivating factor for industrial partners to participate in CRD projects. A few partners provided additional insight into why the CRD project led them to hire HPQ.

> *"We know them because of the collaboration and interaction so it is a safe hire." – Industrial partner*

> *"The HQP spent time at our research facility and he became known to others in the organization so when it came time to suggest that we hire this individual there was clear acceptance of his skills and a desire to hire him." – Industrial partner*

> *"They gained experience in topics of interest to our organisation and gained industrial experience here. Two were hired on this specific grant, five in total from all CRD grants." – Industrial partner*

> *"We treated the collaboration as a long-term interview." – Industrial partner*

In addition, anecdotal evidence from the web surveys and case studies also supports the view that HQP are obtaining employment in their field.

> *"I was able to conduct research in my field of plant ecology and restoration ecology. I was hired as a professor, partly because of my experience in the CRD project. I, myself, was then able to approach other industries to find common objectives and funds for my research. I'm presently working on my on CRD grant with a company thanks to the experience and the specific expertise that I acquired during my PhD (supervised by a Prof. with a CRD grant). I now have four master's students and several undergraduate students who work on my CRD project, all thanks to the experience I gained during my PhD."[27] – HQP*

> *"My participation on the CRD project allowed me to improve my skills and abilities so that I could attain my present position as an associate professor. I was able to become a faculty member as a result of this project and would not have been able to become one otherwise." – HQP*

> *"I am currently the Chief Technology Officer for a spin-off company commercializing the technology developed at the University with funding from this NSERC grant. Being involved in the development of the technology has allowed me to accelerate my career path from basic engineering/project management in to the senior management of a rapidly growing technology company and allowed me to hone my entrepreneurial skills." – HQP*

Finding 22:	After the CRD project, HQP primarily find employment in the private sector and in academia, and at least 10% are hired by the industrial partners. Factors such as the experience, expertise and skills gained through the CRD project help make HQP attractive hires in their field.

[27] *"J'ai pu travailler en recherche dans mon domaine d'écologie végétale et d'écologie de restauration. J'ai été embauché comme professeur, en partie à cause de mon expérience du projet CRD. J'ai pu, à mon tour, approcher d'autres industries pour trouver des objectifs en communs et des fonds pour ma recherche. Je travaille présentement sur ma propre subvention de CRD avec une compagnie, grâce à l'expérience et mon expertise spécifique que j'ai obtenues durant mon doctorat (avec un prof avec un CRD). J'ai maintenant 4 étudiants de maîtrise et plusieurs étudiants de bac qui travaillent sur mon CRD, grâce à mon expertise acquise durant mon doctorat."*

Question 6.4.1: Are HQP involved in CRD projects more "job-ready"?

Question 6.4.2: Do HQP involved in CRD projects require less training once hired?

The findings from the web surveys strongly support the conclusion that HQP involved in CRD projects were more job-ready: 69% of industrial partners who hired HQP agree, as do 77% of academic partners. The majority of HQP themselves agree "to a great extent" that the CRD project has been of value to themselves and their careers (Figure 10). In particular, they strongly agreed (approximately 85% "to a great extent") that there was a good match between the project and their field of study and that their participation in the CRD project had been worthwhile.

HQP who had indicated in a previous question that they were currently employed were asked additional questions regarding the impact to the CRD project on their career (statements marked with an asterisk in Figure 10). These respondents stated that the CRD project had a positive impact on their career path, that the experience gained from the project was important for their current job, that their current job was closely related to their academic field, and that their skills and experience were better matched with those required in their current job as a result of their participation in the project.

> *"During my studies, regular progress reports and industrial site visits gave me valuable exposure to many operations, and a large number of industrial contacts. In my interview with my current employers, much of the experience I spoke about was gained as part of the CRD program. The decision to hire me was largely based on this experience. In each area [I have worked in], I have been able to apply the test design and analysis tools that I learned as a graduate student. I am currently working in my field and have progressively earned increased responsibility. Many of my successes can be linked to my experience in the CRD program." – HQP*

When the HQP responses were broken down based on the type of HQP and their level of interaction with the industrial partner, some interesting trends emerged:

Type of HQP

- A higher proportion (92%) of CRD post-doctoral fellows than other types of HQP agreed that participation in the collaborative R&D project has had a positive influence on their career path; conversely, fewer CRD post-docs found that their current job relates closely to the field in which they completed their academic training (45%) and that their skills and experience are better matched with those required in their current job as a result of their participation in the project (55%). This suggests that some other factor relating to their experience on the CRD project (perhaps networking or dissemination of CRD research results, as well as the management and/or supervisory role they likely played with regard to the CRD project) is responsible for the positive influence on their career.
- CRD doctoral students most often reported that their current job relates closely to the field in which they completed their academic training (80%).
- CRD research associates were the least likely to report that their participation in the project has had a positive influence on their current salary (33%), whereas master's students (67%) and post-doctoral fellows (64%) were the most likely to agree with this statement.

Level of interaction

- HQP who had higher levels of interaction with industrial partners agreed most strongly with the following statements: "My participation in the collaborative R&D project has had a positive influence on my career path", "The experience I gained from the project is important for my current job", and "My current job relates closely to the field in which I did my academic training".

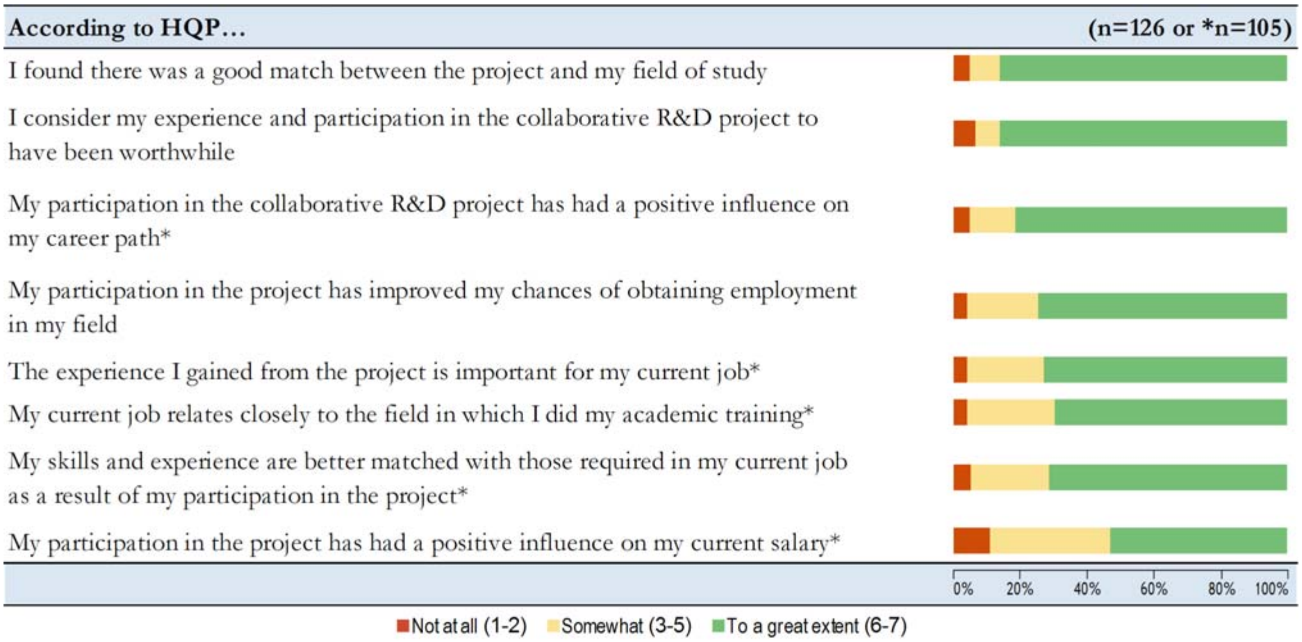

Figure 10 Perceptions of HQP on how their participation in the CRD project has benefited them professionally

Source: HQP web survey

This anecdotal evidence suggesting that HQP involved in CRD projects require less training is supported by the fact that 77% of industrial partners who hired HQP confirmed that the amount of job training received by the HQP they had hired was less that what these individuals would otherwise have required.

Finally, participation in the CRD project may also confer economic benefits to HQP: 42% of HQP survey respondents indicated that their participation in the project has had a positive influence on their current salary, and some of these provided a percentage representing the extent of this salary increase. Indeed, the economic impact analysis found that the contribution of the CRD program to increased productivity of human capital of students participating in CRD project research is reflected in higher salaries they earn after completing their degree. The net increased human capital of the CRD program as a whole (stemming from both NSERC and partner investments in the form of salaries and stipends for HQP) is estimated to be within the range of $43 million to $66 million of impact on GDP.

Finding 23: The majority of HQP benefit professionally from their CRD experience in terms of their career path, their reduced need for training and, in some cases, higher salaries.

4.4 Question 7: Impact on long-term partnerships

Question 7: To what extent has the program established long-term relationships between academic researchers and industrial partners?

Establishing long-term relationships between academic researchers and industrial partners is one of the four intermediate outcomes of the CRD program. The majority of academic researchers—at least 60%—continue to undertake collaborative R&D with their CRD partners after the CRD project, whereas only 9% have no contact at all with industrial partners. Approximately one-third also indicated that they had collaborated with other partners (i.e., partners not involved in the CRD project) shortly after the end of their CRD project (file review data). However, this proportion increases to 51% over time (web survey data, Table XIII). These figures are almost identical to those seen for industrial partners: 62% continue to collaborate with researchers from the CRD project, and 49% have gone on to collaborate with other researchers (Table XIII).

Table XIII Types of long-term links between academic researchers and industrial partners

	Acad. Researchers	Ind. Partners
Collaboration with same partner(s)/researchers	62%	62%
Collaboration with other partner(s)/researchers	51%	49%
Collaboration with same partner(s)/researchers on different research	54%	48%
Collaboration with other partner(s)/researchers on different research	43%	44%
Part of a formal or informal network	38%	55%
Collaboration with same partner(s)/researchers on same research	31%	37%
Collaboration with other partner(s)/researchers on same research	26%	15%
Continuing same research without partner(s)/researchers	19%	12%
Consulting contract	17%	na
No contact with partner(s)/researchers	9%	7%
Other	8%	5%
Total (n)	**453**	**297**

Note: Note: Respondents could select more than one answer.
Source: Web surveys of academic researchers (funded) and industrial partners (funded)

These data are supported by CRD program data indicating that CRD grants are a key mechanism used by researchers to support ongoing research collaborations. Of the 1,078 researchers that held CRD grants during the evaluation period, 359 (33%) had at least one other CRD grant with at least one common partner organization during the period under evaluation. Of those with at least one other CRD grant with at least one common partner, 247 researchers (69%) had one other CRD grant, 60 researchers (17%) had two other CRD grants and 30 researchers (8%) had three other CRD grants. While CRD projects are most often initiated by academic researchers, some evidence suggests that shared initiation (researcher/partner) has increased over the study period. Nonetheless, there remains room to increase the proportion of projects that are initiated by industrial partners and, more generally, industry participation in the program.

Interestingly, data in Table XIII suggest that, in the longer term, both on-going and new collaborations shift from projects that focus on the same research as the CRD grant to projects that undertake different research. While the file review found that a similar proportion of academic researchers collaborated with their CRD industrial partners on the same research as they did on other research, web survey data show that a greater proportion of academic researchers collaborate with these partners on different research (54%) than on the same research (31%). A similar shift is observed in collaborations undertaken with new partners (Table XIII). Thus, most researchers and industrial partners do not stop collaborating when their research projects reach their objectives and the follow-up work has been undertaken; instead, they find new research to undertake collaboratively. This finding is supported by program data that indicates that of the 1,078 researchers that held CRD grants during the evaluation period, 392 (36%) had applied for another CRD grant after the start of their last CRD grant within the period.

Another interesting finding is the difference between the proportion of academic researchers who maintained links with industrial partners though formal or informal networks (38%) compared to the proportion of industrial partners who use these networks to maintain contact with academic researchers (55%). This suggests that networks (especially formal networks) could be used by NSERC to help increase industrial partners' access the CRD program. An association also exists between the use of formal and informal networks and grant size: a greater proportion of organizations involved in small or medium grants maintained links with academic researchers through a formal or informal network than partners involved in large grants. This is not surprising, given that large grants represent a bigger commitment by industrial partners, leading to a closer type of interaction between project partners than that offered through networks. No other associations were found between the types of links industrial partners maintained with academic researchers and grant size or between RPP sectors.

Case study data illustrate how CRD projects have sometimes been used to establish long-term relationships between academic researchers and industrial partners. Three of the six cases involve follow-up and/or ongoing collaborative work: two received at least one subsequent CRD grant, and the third has relied on support from the industrial partner and the MITACS program. One exceptional case involves a 20-year partnership between a university research team and an industry consortium, one that was awarded a series of consecutive CRD grants. In this case, each subsequent project is determined by the previous research outcomes—the academic researcher and industrial partners jointly decide on the next project as the current one is drawing to a close, and then the researcher writes the actual CRD grant application on his own. In two other cases, follow-up work was not deemed necessary, whereas in the sixth case, the industrial partner currently has plans for a future CRD grant (possibly with the same researcher) but needs to ensure that it has the financial means in place for the matching funds before moving ahead.

Finding 24: Several long-term relationships between academic researchers and industrial partners have been established through the CRD program, with over 350 teams seeking further CRD funding.

5 KEY FINDINGS – COST-EFFECTIVENESS

To what extent is the CRD program efficiently achieving its intended results?

5.1 Question 8: Effective and efficient program delivery

This section will explore questions related to the effectiveness and efficiency of the means used to deliver the CRD program and provide evidence in support of recommendations for increasing the efficiency and overall impact of the program. This evidence necessarily draws on the findings from the three previous evaluation issues (i.e., relevance, design and delivery, success and impact).

Question 8: Are the most effective and efficient means being used to deliver the CRD program?

All key informants agree that the CRD program is an effective means for industry to access the knowledge, expertise and resources of Canadian post-secondary institutions. This finding is in line with the views of key informants on the effectiveness of the CRD program to initiate and support collaborative R&D projects (see Section 2.2). Consistent with the perceptions of key informants, industrial partners strongly support the statement that the CRD program is "an effective mechanism" for their organization to "access the knowledge, expertise and resources of Canadian post-secondary institutions", rating it 6, on average, on a scale of 1 to 7 (where 1 means "not at all" and 7 means "to a great extent"). Combined with the fact that 93% of industrial partners consider their contributions to the CRD project to have been a worthwhile investment, this suggests that they also consider the CRD program to be a cost-effective means to access university research results.

Most of the main elements of the program's delivery that contribute to the effectiveness and efficiency have already been discussed under Section 3.1 (i.e., factors that facilitate access to the program), such as the flexibility of the CRD program and its stability over the years. In addition, key informants identified program staff as a key factor in the efficiency and overall success of the program. However, some indicated that the program needs to improve its communication with stakeholders, including those within government and in the private sector.

Another indicator of the efficiency of the CRD program is the contribution made by industrial partners: the level of cash and in-kind commitments honoured by partners were high over the period from FY 2004 to FY 2007. In the grant files for FY 2004 and FY 2005, only 6% of projects had not received cash commitments and the same number had not yet received any in-kind commitments. Similar levels of contributions were attained for projects completed in FY 2006 and FY 2007: only 6% and 9% of projects had partners that did not honour cash or in-kind commitments, respectively.

Contributions can also be assessed based on the leverage ratio—i.e., the ratio between partner contributions and the CRD funds awarded by NSERC. Based on program data, the CRD leverage ratio was $1.56 (cash and in-kind) on average for every $1 invested by NSERC between 1998–1999 and 2007–2008. Overall, this leverage ratio is highly comparable to three similar programs offered in California (the University of California's Discovery Grants Program, at $1.57), Australia (the Linkage Projects Program, formerly called SPRIT, at $1.40–$1.90) and the UK (the Collaborative R&D Programme, formerly called the DTI Technology Programme, with a ratio of about 1:1); see further details on these programs in Appendix 2.

Compared to other NSERC programs, the CRD program is unique given its 1:1 NSERC-to-partner contribution ratio (with partner's cash contributions representing at least half of the funding request made to NSERC), as well as the fact that the program is not cash limited (i.e., there is no minimum or maximum NSERC grant amount). Other NSERC programs that include ratios for partner contributions typically have a lower minimum cash contribution, are not mandatory, and/or feature a maximum grant amount (e.g., $100,000 maximum). Available information on similar federal government programs also indicate that funding ratios are typically less than that of the CRD program and/or include a maximum program funding amount. For example, CIHR's Industry-Partner Collaborative Research Program include different CIHR-to-industry funding ratios (1:1, 1:2 and 1:4) depending on the phase of the study (e.g., clinical trials), but the CIHR funding is limited to $5 million per competition and up to $500,000 per year for up to five years per grant.[28]

At the provincial level, the available information indicates that the funding ratios of government-to-partner are typically lower than 1:1 and feature a maximum program funding amount. Of note, the Ontario Research Fund's Research Excellence Program provides funding for new, leading-edge research initiatives that feature scientific excellence and commercialization in focus areas. The program will contribute one-third of the operating costs of the initiative, with another one-third coming from the private sector and the remaining one-third from the funded institution.[29] The program will provide a minimum of $1 million and a maximum of $8 million in support to the initiative.

Finally, program data reveal some small differences in terms of leverage ratios between RPP sectors and based on organization size. Indeed, leverage ratios for the Food and Bio-Industries sector ($1.47 per award dollar) are slightly below that of the ICM ($1.60) and Environment and Natural Resources ($1.59) sectors. However, when examining the leverage ratio based on cash only (i.e., excluding in-kind contributions), the Food and Bio-Industries ($0.91) and ICM ($0.88) sectors had a higher ratio than the Environment and Natural Resources sector ($0.83). Interestingly, large organizations had slightly higher leverage ratios (for both cash and in-kind) than did SMEs, but when only cash contributions were considered, small and large organizations both had larger ratios than medium-sized organizations.

Finding 25: Multiple lines of evidence indicate that the CRD program is efficient and effective, particularly in providing industrial partners with access to university research results and in leveraging private sector funds for collaborative R&D.

Question 8.1: Can the efficiency of the CRD program be improved (i.e., can outputs be produced in a more affordable manner)?

A useful measure to assess the efficiency of program delivery is the ratio of the administrative cost for the CRD program to total CRD grant funds awarded (Table XIV). An estimate of the administrative cost for the CRD program is only available for seven of the ten fiscal years under review (i.e., 2001–

[28] CIHR, Operating Grant: Industry-partnered Collaborative Research. Accessed March 25, 2010: http://www.researchnet-recherchenet.ca/rnr16/viewOpportunityDetails.do?prog=772&language=E&fodAgency=CIHR&view=browseArchive&browseArc=true.

[29] Ontario Ministry of Research and Innovation, Research Excellence Program Overview. Accessed March 25, 2010 http://www.mri.gov.on.ca/english/programs/orf/re/program.asp.

2007). Overall for this period, the administrative cost (operating ratio) was 5.9%, compared to 5.7% for the RPP division and 4.5% for NSERC as a whole using the same approach. Table XIV shows that the CRD program has been delivered in a cost-efficient manner, with the operating ratio trending downward over the period covered by the evaluation (from 6.8% to 5.1%).

Administrative costs for the program include both the direct and indirect costs of administering the program. Direct costs are comprised of salary[30] and non-salary costs, which are related primarily to the adjudication of the award. Non-salary costs also include a share of the costs of relating to corporate representation and general administration for the RPP directorate. Other direct costs associated with administering the program, such as post-award management (which is a centralized function carried out by the Finance division) and indirect costs, such as common administrative services for NSERC (e.g., finance, human resources and IT) cannot be provided at the program level. These other direct and indirect costs have also been included in the total calculation of costs and were estimated using the ratio of total CRD grant funds to total NSERC grant funds.

Table XIV Percentage of estimated direct and indirect CRD program spending in relation to total CRD grant funds awarded

	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Direct Salary	$558,815	$666,578	$695,422	$703,405	$797,284	$961,828	$1,011,917
Direct Non-Salary	$80,945	$66,607	$91,943	$66,906	$70,912	$74,865	$56,380
Total direct costs	$639,759	$733,186	$787,364	$770,311	$868,197	$1,036,693	$1,068,297
Indirect costs	$1,040,691	$1,041,352	$932,861	$894,262	$953,427	$1,118,989	$1,182,312
Grants Funds Awarded	$24,575,907	$26,604,850	$27,950,639	$29,677,562	$32,450,647	$37,581,628	$44,413,881
Operating Ratio							
Direct	2.6%	2.8%	2.8%	2.6%	2.7%	2.8%	2.4%
Indirect	4.2%	3.9%	3.3%	3.0%	2.9%	3.0%	2.7%
Operating Ratio	**6.8%**	**6.7%**	**6.2%**	**5.6%**	**5.6%**	**5.7%**	**5.1%**

Note: Indirect costs include expenses indirectly attributable to the program, such as common administrative services, as well as other direct expenses (e.g., post-awards management, is a centralized function carried out by the Finance division) which are not available at the program level. Salary estimates exclude employee benefits (EBP).

Source: NSERC; estimated direct and indirect program spending not available prior to FY2001/02.

It should be noted that a recent activity-based costing exercise undertaken by RPP to estimate staff time per program for FY 2009–2010 estimated the total direct costs (salary and non-salary) for the CRD program to be 4.1%. This estimate is higher than the average total direct cost estimate of 2.6% for the period, but is likely closer to the actual total direct costs because it is based on estimations of the amount of time spent by each RPP staff member administering the program and, as such, better reflects the additional staff time required to administer the CRD program in comparison to other RPP and NSERC programs. For example, in contrast to an annual competition, the procedure used for the CRD program involves the ongoing receipt and processing of applications, resulting in an iterative application review process wherein RPP staff provide feedback on applications and applicants can re-submit applications based on this feedback. Although the activity-based direct cost figure cannot be

[30] Salary estimates exclude employee benefits (EBP).

extrapolated backward for the period in question, the figure suggests that the operating ratio for direct costs in Table XIV is likely a somewhat conservative estimate for the CRD program.

In relation to this finding, comments from program stakeholders—particularly in light of the recent scale-up in administrative costs proportional to increases in amounts awarded (Table XIV)—suggest that any increases in the cost-efficiency of the CRD program could come at the price of slow-downs in the delivery of the program, more particularly with regard to processing of CRD grant applications. Further efforts to increase the affordability of the program should be balanced against the effectiveness of program delivery. The program is already viewed by internal key informants as quite streamlined, considering the high level of involvement in grant administration by program staff.

That is not to say that potential improvements to the CRD program are not possible. Indeed, stakeholders both internal and external to NSERC stressed that certain incremental adjustments could be beneficial, but that any changes to the design and delivery of the CRD program should be made with care. To quote one survey respondent (whose opinion was shared by several other academic researchers and industrial partners): "If it ain't broke, don't fix it." Indeed, 17% of academic researchers and 4% of industrial partners explicitly stated that no improvements were necessary. Approximately 250 academic researchers (58%) and 80 industrial partners (27%) provided suggestions when asked, "What areas of the CRD program (if any) do you feel need improvement?" Overall, suggested improvements most frequently involved ways to increase the efficiency of grant management, as well as to increase the reach of the program and the breadth of its impacts. Many of these improvements have already been outlined under Questions 2.1 and 3.

As discussed in Section 3.1, the time and effort required to prepare an application (particularly short-term or small projects) may sometimes inhibit participation in the CRD program, whereas reporting requirements and project administration more generally were found to limit the time that researchers can spend on research, particularly for large-scale projects and those that involve a large number of industrial partners. Thus, on the one hand, streamlining the application process and reporting, especially for small grants, would also allow for faster turn-around time on funding decisions (which is another improvement sought by both academic researchers and industrial partners). On the other hand, allowing for project management expenses to be compensated or supported by CRD funds would increase the efficiency and impacts of the projects themselves. In fact, following the end of the evaluation period, NSERC changed its policies to allow for up to 10% of the total cash contributions to the project (from all sources) to be allocated to project management expenses in order to "ensure integrated coordination of research activities and timely delivery of research results to partners."[31] Principal investigators are not themselves eligible for compensation under these new guidelines, but hiring a separate project manager to conduct these activities will likely free up valuable time for academic researchers.

Dedicated project management funds would also help to address some of the issues relating to timing, use of funds and flexibility of research objectives for CRD projects, but it remains to be seen whether the new guidelines will meet the needs of academic researchers. Other issues that relate to funding will also likely remain. Seeing the extent to which cash contributions of partners can limit access to the CRD

[31] NSERC, 2009. Guidelines for Research Partnerships Programs Project Management Expenses. Accessed March 2010 from: http://www.nserc-crsng.gc.ca/Professors-Professeurs/ManagementExpenses-CoutsGestion_eng.asp.

program (Section 3.1), the need for greater flexibility in terms of matching cash contributions, as expressed by both academic researchers and industrial partners, is probably justifiable (Section 2.2). This is particularly true for SMEs, but also possibly for the RPP sectors (or specific industries within these sectors) that have been most affected by the economic downturn.

Moreover, although the flexibility of the CRD program has been repeatedly cited as a key strength of the program, academic researchers have suggested there may also be additional room for flexibility in terms of funds management and project period. For example, several respondents explained how increased flexibility in the project period (especially the starting and ending dates) would allow for more effective recruitment and training of students/HQP, coordination with industrial partners, and preparation of publications and other follow-up activities.

> *"There are significant hurdles that have to be crossed before applying for a CRD grant becomes worthwhile. One of the biggest practical problems for projects that involve students is trying to coordinate the initial project agreement with the industry partner, then applying for the grant, and then looking for a suitable student. These steps have to be taken in this sequence (you can't recruit a student without a project and funding in place), but typically once the grant is awarded the clock starts,[32] so there is a scramble to find a suitable student. This may not result in the optimal match between project and student." – Academic researcher*

With regard to flexibility in the use of funds, academic researchers suggested that a greater proportion of funds could be allowed for transfer of amounts between funding categories in order to increase their capacity to hire non-student staff and to apply the funds to the purchase of equipment, for example.

Other improvements suggested by academic researchers and industrial partners with regard to program delivery were generally related to difficulties that arose in a small number of CRD projects (e.g., reviewers that were not familiar with applied research, inconsistencies in support/advice offered by program staff). These should be not considered wide-spread problems, but they represent examples of potential issues that may be encountered.

Finally, the outstanding need for better outreach and support mechanisms to establish relationships (see Section 2.2) also ties with the suggestion for better awareness and visibility of the CRD program. Thus, clearer information on NSERC's updated IP policy (as well as on partner eligibility guidelines) could be provided as part of these outreach efforts, as well as information on opportunities and assistance to improve IP agreements and management. This would be beneficial because, in spite of improvements to NSERC's IP policy, IP issues were found to represent a stumbling block for certain CRD projects, both at project initiation (see Section 3.1) and during later stages of CRD projects. However, key informants and case studies suggested that part of these issues might stem from a lack of experience and understanding with regard to IP and changes in NSERC's policy.

From a broader standpoint, greater assistance for relationship-building and greater industry education about the program through increased outreach and visibility are expected to lead to increased participation, which will further increase the reach and breadth of impacts of the CRD program.

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[32] According to NSERC, applicants usually get to chose their Start Date, so they have the option of choosing a date in the future (e.g., April 1 and Sept 1 are popular choices for Start Dates).

"[There is a need for] motivation for industry to engage with university researchers. NSERC could spend more effort to educate industrial partners about the benefits of collaborating with universities. Industrial partners, especially small companies, tend to view graduate students as cheap labour, missing the big picture (generation of HQP for hire, availability of faculty for consulting, improved ability to pursue other substantial industrial funding such as IRAP, AIF)." – Academic researcher

Finding 26: Improvements to the CRD program—such as through greater flexibility in fund use and partner cash contributions, adjustments to the application process and more program visibility—should primarily aim to enhance grant management efficiency and its breadth of impacts but should not affect fundamental aspects of the program's design or delivery.

6 CONCLUSIONS AND RECOMMENDATIONS

The present evaluation finds that the CRD program is relevant, well designed, appropriately delivered, and generally provides considerable long-term benefits to industrial partners, academic researchers and HQP. The conclusions and recommendations here are supported by the key findings of this evaluation (findings are identified by number in parentheses).

A key strength of the program is its flexible design, which has allowed it to remain relevant over a long period with regard not only to government and NSERC plans and priorities, but also to the continued and emerging needs of its key beneficiaries: industrial partners, academic researchers and HQP (1, 2, 4, 5); in fact, this program's design ensures that it is aligned primarily with the needs of industry, rather than respond to government plans and priorities. The CRD program occupies an important niche among alternative sources of support in Canada and is effective at initiating and supporting university-industry collaborative R&D projects (2, 3, 25). While pre-existing relationships between academic researchers and industrial partners are a key facilitator for access to the program, the program's longevity and effectiveness have contributed to building long-term partnerships among many collaborators, approximately 30% of which have participated in subsequent CRD projects (5, 24). The effectiveness of the program is demonstrated through a wide variety of benefits and outcomes stemming from CRD grants. These impacts not only align with the expected outcomes of the program, but also add value for program beneficiaries in terms of relationship-building, access to HQP and societal impacts (Findings 7–25). In addition, an economic impact analysis of the CRD program as a whole indicates a positive return on investment on the Canadian GDP (14).

Potential improvements to the CRD program mainly relate to ways in which the program's delivery could be more efficient and better meet outstanding needs, as well as ways in which the impacts of the program could be expanded across a broader portion of the Canadian industry (4, 6, 26). However, the fundamental aspects of the program's design or delivery are not in question here (25, 26). Certain changes have already been undertaken by NSERC to better address the needs of program stakeholders; among other evidence, this indicates that CRD program staff and management are attentive and responsive to feedback provided by the beneficiaries of the program.

Potential improvements that should be considered by NSERC include:

- Streamlining the application process and decreasing the turnaround time for small grants, which would allow for increased access to the program among certain sub-groups of researchers and partners and provide opportunities to develop new university-industry relationships (4, 6). This also relates to the rationale provided for Recommendation 3, but implementation should be considered within the CRD program itself rather than through a separate program.
- Providing opportunities for more flexible or reduced industrial partner cash requirements, particularly for SMEs, but also possibly for RPP sectors (or specific industries within these sectors) that have been affected by economic hardships (4, 6, 26).
- Increasing the flexibility with regard to the use of funds, i.e., the proportion of the budget that can be transferred between funding categories and/or timing in the use of funds throughout the project period. As academic researchers must coordinate planning and fund allocation for CRD projects with both HQP and industrial partners, this flexibility would help to enhance the success and impact of CRD projects (4, 5, 26).

- Monitoring the effectiveness of changes that have already been undertaken (i.e., NSERC's IP policy and project management expenditures), as well as future incremental adjustments, with regard to the needs of program beneficiaries and the efficiency of program delivery (6).

- **Recommendation 1**: Maintain the CRD program in its current form. Incremental improvements to program delivery should continue to be made in response to changes in the research landscape, in the needs of key beneficiaries, and in the number of CRD grants.

The primary beneficiaries of the program—industrial partners—report a high level of satisfaction and a wide range of benefits from their participation in CRD projects, as well as a high rate of continued participation in collaborative R&D after the CRD project (7, 8). Clearly, the CRD program enables industrial partners to benefit from collaborative R&D with university-based experts on well-defined projects within the context of a wide variety of different needs and corresponding project objectives (25). The vast majority of industrial partners report that they have gained new knowledge from the research results, and 80% have observed concrete impacts stemming from the use of the new knowledge and technology developed through the CRD projects (9). As projects that did not receive CRD funding either did not proceed or were typically more limited in scope and impact, this suggests that many impacts stemming from CRD projects would not have occurred in the absence of program funds (3).

Many examples of the impacts of CRD grants were observed, such as new products and services, which often allowed for increased competitiveness, to new or improved processes, which often led to increased productivity (10, 12). Furthermore, broader socio-economic impacts and organizational benefits, such as enhancement of R&D activities, long-term relationship-building and access to HQP, should not be underestimated as factors that both encourage the participation of industrial partners in CRD projects and add value to these grants (11, 13, 14, 24).

Despite an appreciable reach of the program among Canadian firms and a growing number of firms participating in CRD projects, there remains room to increase awareness of and "buy-in" to the CRD program among the business sector (3, 26). As NSERC has recognized, organizations that can act as "gateways" to reach firms, such as industry associations, centres of excellence and university-industry liaison offices already help to facilitate access to the program and could be useful avenues through which to increase the outreach and visibility of the program.

- **Recommendation 2:** Increase the outreach and visibility of the CRD program—particularly among industry—to promote awareness about the design and benefits of the program among stakeholders and to increase industry "pull".

As the program also benefits academic researchers, the increased visibility of the program and its achievements within the academic community would also help to increase awareness of and participation in the program. The findings of this evaluation show that academic researchers who participated in collaborative R&D with industrial partners pursued and achieved a wide variety of objectives, not only because of the availability of CRD funds to conduct research but also because of the high level of involvement of industrial partners and the participation of students (15). They created and extensively disseminated new knowledge and technology to the industrial partners, as well as within academic community, through multiple publications and conferences (16). At least 135 patents, 45 licenses (at least half of which generated revenue) and 26 spin-off companies were also reported in the web surveys (this represents approximately 460 CRD projects: an exact count for these outputs could not be determined across the evaluation period; 16). Moreover, academic researchers also report that the CRD program helped to enhance and shape their research programs, their reputation and their teaching, thus contributing to broader benefits for other researchers, their institution and Canada (17, 18).

However, opportunities for researchers to access and benefit from the program were most often limited by the cash requirements for industrial partners (particularly for small and medium enterprises) and the workload and timeframe involved in the application process (especially for small/short-term CRD projects) (6). Meanwhile, pre-existing relationships facilitated the development of shared expectations and good communication between academic researchers and industrial partners, leading to better access to the program and increased success of CRD projects (5, 16). This is very consistent with NSERC's observation that successful long-term collaborations often begin as a small joint collaborative R&D project that tests the potential value of the university-industry relationship. These considerations suggest an opportunity for a smaller, more focused version of the CRD program that specifically addresses these issues. Some related improvements could also be made to the existing CRD program, as outlined in Suggestions 1 and 2.

- **Recommendation 3:** Pursue plans to explore a Pre-Collaborative Research and Development (Pre-CRD) grant pilot program, with a reduced requirement for partner contributions and a streamlined application process.

Academic researchers also play a crucial role in the recruitment, coordination and training of HQP within the context of the CRD program. This is the first time that evidence relating to the impacts of the CRD program has been collected directly from HQP. The findings of the evaluation show that the opportunities for HQP contributions to CRD projects were significant, not only in terms of the number and length of time that HQP were involved in CRD projects, but also in terms of interaction with industrial partners and subsequent professional and financial benefits for HQP (19, 23). Indeed, the evaluation clearly shows that—especially through their interactions with industrial partners and their exposure to R&D in industrially-relevant environments—participating HQP acquired valuable skills and experience (20, 21). As a result, HQP were often judged by industrial partners as "safe hires" and generally needed less training once hired (22, 23). Not surprisingly therefore, a large proportion has since found employment in their field—including 10% within the industrial partner's organization (22). Additional evidence suggests HQP involvement in CRD projects also builds capacity for future collaborative R&D (in both the academic and private sectors) in their field and contributes importantly to the program's overall economic impact through increased human capital (14, 21, 23).

On the strength of this evidence, this evaluation concludes that HQP serve as an integral part of the CRD program in two key ways: first, in contributing to the R&D undertaken with and for industrial partners, and second, as trainees and potential hires (especially for students), leading to increased human capital and associated economic benefits. These findings are all the more interesting because changes were made to CRD program requirements during the evaluation period to specify that HQP should include graduate students. In addition, some internal key informants placed considerably less importance on benefits for HQP than on benefits to industrial partners and academic researchers, suggesting a need to highlight and reinforce the key role of HQP in the CRD program within NSERC. Considering that one-third of industrial partners see a benefit in increasing their access to HQP, as well as in light of Recommendation 2, greater awareness of the benefits of the CRD program among HQP could also help to enhance the reach and perception of the program among stakeholders of the program, particularly industrial partners.

- **Recommendation 4:** Maintain support for the participation of HQP—including students—in CRD projects. As part of Recommendation 2, communicate more prominently to program stakeholders both the contributions of HQP to CRD projects and the benefits of CRD participation for HQP.

Several lines of evidence also point to the potential for greater benefits of participation in CRD projects for small and medium firms than for large firms. In particular, SMEs generally see greater effects in their R&D budget, management and staff than large firms (13). It is worth noting that increases in the number of small firms participating in CRD projects have already been observed during the latter half of the study period. However, Suggestions 1 and 2 and Recommendations 2 and 3 will help to increase reach, access and benefits of the CRD program for this sub-group of firms.

Finally, the effectiveness of the program is such that it should be viewed as a model for other funding organizations—such as those in the health or social sciences sectors—that offer or develop collaborative R&D. Increased visibility of the program and its benefits for academic researchers, industrial partners and HPQ among Canadian government and business sectors outside of the NSE could help to demonstrate ways in which this program could serve as a model for other programs that support collaborative R&D.

A METHODS

This section includes a description of the overall approach (Section A.1) and a summary of the data collection methods used (Section A.2).

A.1 Overall Approach

This evaluation used multiple indicators and lines of evidence to address the evaluation questions (see Section 1.4): document/file review (including review and analysis of administrative data, such as those found in NAMIS and the results of past evaluation projects), grant file review, 35 interviews (7 key informants and 28 for case studies), and 5 web surveys. Moreover, two higher-level analyses made use of the collected data: the economic impact analysis and six case studies. The last phase of the evaluation—meta-analysis and reporting—drew from all of the data collected and analyses performed in the previous phases. The data collection matrix (DCM), presented in Appendix 1, cross-links the evaluation issues and questions with indicators, data sources, and methods. Figure 11 illustrates how the methodological instruments and deliverables relate to one another and to the main phases of the evaluation; note that this report is represented in orange.

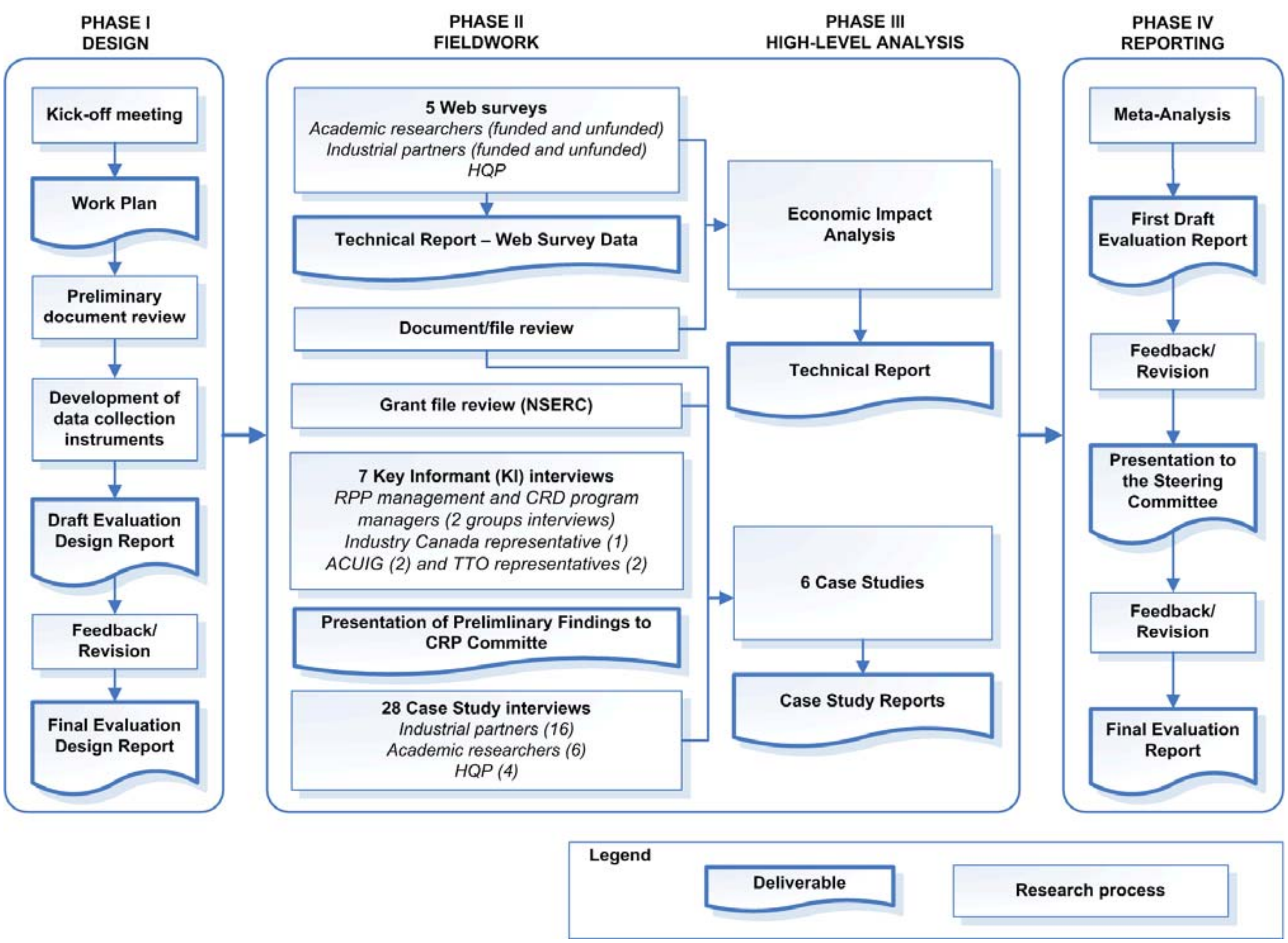

Figure 11 Evaluation overview: phases, processes and deliverables

A.2 Data Collection Methods

The data collection instruments for each method were developed during the design phase, which involved an in-depth review of evaluation questions, indicators, data sources and collection methods in the DCM, and a cross-linking of indicators with each of the instruments. These instruments were developed on the principle that they should be aligned as clearly as possible with indicators in the DCM, and that they should be consistent and enable comparisons with data collected as part of previous studies and evaluations.

A.2.1 Review of program documents and information

The review of program documents and information was conducted in two parts: 1) a preliminary review was performed during the design phase to provide the evaluation team with the information needed for designing the study and the data collection instruments, and 2) the full document and program information review was completed during the fieldwork phase, as specified in the DCM.

Documents/literature, files and program data that were reviewed include:

- CRD program documents, including program descriptions and eligibility information, past evaluations and performance indicator studies, and final research report templates and application forms;
- CRD program research and analysis documents, including reports from the 2000 and 2002 two-year follow-up telephone surveys conducted with industrial partners and academic researchers, and the review of 276 grant files from 2004–2005 and 2005–2006 that was completed in 2007;
- departmental documents, including RPP and NSERC information;
- relevant federal government documents, i.e., on priorities relating to R&D and S&T;
- other documents/literature related to university-industry collaborative R&D, including secondary data on corporate R&D spending, the impacts of government R&D programs, and tools and methods for the assessment of research impacts (e.g., the success case method); and
- program data extracted from NSERC's administrative database (NAMIS), provided by NSERC in the form of an Excel file which contains, among other data, contact and grant information for both academic researchers and industrial partners, as well as unsuccessful researchers and industrial partners.

A.2.2 Grant file review

The review of grant files was conducted by NSERC during the fieldwork phase, based on a file review guide developed in collaboration with Science-Metrix. This guide identified where information was collected from the files (e.g., final research reports, partner letters), with cross-linking with relevant indicators in the DCM. More specifically, data were extracted from program grant files compiled by NSERC for closed grants with an end date in either 2006–2007 or 2007–2008 (fiscal years). These data were compared with data collected in 2007 by the Innovation Institute of Ontario for its output and outcome analysis covering the 2004–2005 and 2005–2006 fiscal years. While the nature and extent of the data vary between grants and over the time period in question, a typical grant file contains the following: grant application; letters of support from industrial partners; progress and final reports which provide information on the planned and actual activities of grant recipients; and statements of account for each year of the grant which provide information on the planned and actual use of grant funds.

A.2.3 Key informant interviews

A total of 35 interviews were conducted, including 7 key informant interviews (with 11 interviewees) and 28 interviews conducted as part of the case studies (see Section A.2.6). Key informants provided primarily qualitative data on the perceptions and opinions of individuals who have had a significant role in the design and delivery of the CRD program, who have experienced the delivery of the program, or who otherwise have a stake in the program. Interview guides were designed to ensure that questions are aligned with the evaluation questions and indicators identified in the DCM.

The seven key informant interviews were conducted with the following:

- RPP management (n = 1 group interview, with 3 interviewees);
- CRD program managers (n = 1 group interview, with 3 interviewees);
- Industry Canada representatives (n = 1);
- Members of the Advisory Committee on University-Industry Grants (ACUIG) (n = 2); and
- University Technology Transfer Office (TTO) representatives (n = 2).

A.2.4 Web surveys

Web surveys were designed to provide quantitative and qualitative data in relation to the core evaluation questions, as well as to support the study of social and economic impacts. Web surveys extended the scope of the evaluation by reaching a far wider audience than permitted by interviews alone. The web surveys were cross-linked with the DCM to ensure that data collection via the surveys addressed evaluation questions with regard to relevance, design and delivery, success and impact and cost-effectiveness. Five web-based surveys were administered to five groups; sample populations and response rates are presented in Table XV.

Table XV Response rates for five web surveys

Web survey	Initial sample	Invalid emails	Attrition	Valid sample (N)	Completed	Valid response rate†	Margin of error‡
Academic researchers	1045	12	36	997	448	44.9%	±3.44%
Industrial partners	1495	459	69	967	288	29.8%	±4.84%
Unfunded academic researchers	223	3	11	209	92	44.0%	±7.66%
Unfunded industrial partners	169	12	52	105	29	27.6%	±15.56%
HQP*	164	0	0	*355*	138	*38.9%*	*±6.53%*

Notes: † Valid response rate = Number of completed surveys, divided by the total valid sample (N), which excludes unreachable potential respondents.
‡ 95% confidence level (19 times out of 20).
* The total population of HQP who participated in CRD projects during the evaluation period is not known. A total of 164 HQP volunteered to participate through the sampling approach. However, a conservative estimate suggests that at least 355 HQP were sent an invitation to participate by an academic researcher. The response rate and margin of error are thus *estimates* based on a sample population of 355.

A.2.5 Economic impact analysis

The economic impact analysis was designed to estimate the CRD grant program's contribution to the Canadian economy. This analysis examines the presence of additional economic benefits (Evaluation Question 4.2.1). This work comprises two main types of analyses: 1) estimation of the *static impact* based on an input-output simulation of the effect of program-related expenditures on the Canadian GDP (both the gross and net static impacts were estimated); and 2) estimation of the *dynamic impact* of the supported projects (including their contribution to the training of HQP, their contribution to Canadian R&D and to Canada's total factor productivity growth). The latter estimates included both a top-down approach, which proceeds by decomposing the growth of multifactor productivity[33] of the economy in its constituting components down to the contribution of university education and research activities to GDP growth and, 2) a bottom-up approach, which estimates the effect of the program based on econometric analysis of micro-data observations of firms and researchers involved in the program.

Data for the economic impact analysis were extracted from program data (i.e., NAMIS file provided by NSERC, see Section A.2.1), secondary data (e.g., Statistics Canada tables), and the web surveys (Section A.2.4). In addition, the details of the budgets for 67 projects (i.e., approximately 20 per RRP sector, distributed evenly before and after 2002) were extracted using stratified random samples from small, medium and large projects listed in the program grant files.

A.2.6 Case studies

The case study approach was used to increase the evaluators' understanding of the essential conditions for long-term success and to provide an in-depth account of the impact of CRD program grants on industrial partners, academic researchers and HQP, particularly with regard to the objectives and expected intermediate outcomes of the CRD program. Six case studies were conducted in completed CRD projects to trace and measure the transfer and use of research results, as well as longer-term socio-economic impacts, particularly on the industrial partner and, more generally, on Canada.

A multi-criteria selection process was used to provide an appropriate sample of CRD projects. Potential cases were identified based on (1) email solicitation of NSERC managers and officers who were actively involved in the CRD program between 1998 and 2007 to identify exemplary CRD project(s); and (2) analysis of file review data and (when available) review of responses to researcher and industrial partner web surveys. Efforts were made to ensure that selected CRD projects were balanced as best as possible across these criteria:

- RPP sector (i.e., two cases per sector);
- Region/province of industrial partner and/or university of the academic researcher(s);
- Size of partner contributions;
- Timing (i.e., projects completed before 2002 and after 2002);
- Type/objectives of CRD project (e.g., increase knowledge base of industrial partner; develop new or significantly improved good or service; develop new or significantly improved process);
- Success/level of achievement: Projects were rated as having been successful or having had mitigated success based on project metrics, commercialization of research results, impact on industrial partners, impact on researchers and impact on HQP.

[33] Multifactor productivity growth is a function of the growth of human capital (measured by level of education and work experience) and innovation (approximated by an indicator such as R&D employment or expenditures) in Canada and spillovers from innovations and technological progress abroad. The change of multifactor productivity is the change in GDP that is not explained by the change in the quantity and quality of labour and the stock of productive capital. Thus, it is usually interpreted as the result of technological change.

Relevant data on the selected CRD projects were extracted from available program documents and files, including grant applications, scientific and technical reports, final research reports and other progress reports or information on the planned and actual activities and use of funds (see Section A.2.1). Where applicable, websites (particularly those of the industrial partner) were consulted to confirm or complete evidence provided during the interviews. In addition, the case studies were based on information collected in a total of 26 interviews, which were conducted with the following respondent groups:

- Academic researchers (n = 6, one per case);
- Representatives from industrial partner organizations (n = 16, at least one per case); and
- HQP (n = 4, no more than one per case).

When necessary, additional individuals were contacted to obtain corroborating details (e.g., representatives from Technology Transfer Offices involved in some stage of the CRD project, additional HQP). The results of the case studies were presented individually, as well as comparatively through a cross-case approach for the socio-economic impacts, which also informed the meta-analysis. Findings from case studies also provided supporting material to exemplify findings from other lines of evidence, such as those from the surveys or economic impact analysis.