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Data and the measurement of R&D program impacts

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ABSTRACT

The purpose of this paper is to propose a research agenda for the measurement of economic impacts of Canadian government R&D support programs. Different methodologies and indicators used to assess benefits from government support programs/agencies for R&D are discussed first. Using available information on major business-related R&D federal programs, the paper will assess which indicators and methodologies can be implemented. The specific programs/agencies under investigation include: Technology Partnerships Canada sponsored by Industry Canada, Industrial Research Assistance Program sponsored by National Research Council, Atlantic Innovation Fund sponsored by Atlantic Canada Opportunities Agency, Canadian Space Agency and National Defence.

1. Introduction

There have been a number of recent papers in this journal that investigated the effects of government R&D programs on innovation and economic growth (Feller, Ailes, & Roessner, 2002; Kostoff, 1995; Luukkonen, 1995; Martin, 1998). While there appears to be general consensus as to what sorts of evaluations are theoretically possible, there is little agreement on what is possible practically. The current Conservative federal government in Canada is interested in value for money in terms of their expenditures on R&D programs. This paper represents an early stage investigation to help inform the government of what is possible. The problem of measurement, however, is a difficult one. From my experience with Canadian program evaluation the main problem is a lack of data on outputs from R&D programs. The aims of this paper are to reiterate the reasons for government R&D support programs, to summarize five existing Canadian programs, and to propose a method for analyzing the socio-economic impact of these programs.[2]

Technology policy stems from the neoclassical belief that because of knowledge and technical spillovers there will be a market failure in the research and development conducted by private firms. The government's answer to this dilemma is technology policy. What is Canadian technology policy? It can be viewed as a set of institutions designed to increase the rate of technological change. Increasing technological change occurs when the rate of product and process innovations increases, when the rate of adoption/diffusion of new technology increases or some combination of the two. The federal government is quite dedicated to "innovation" as is evidenced by their presence on the Internet at (www.innovation.gc.ca). In 2005/2006 the federal government's expenditure on science and technology (S&T) is expected to be $9.1 billion. Approximately $5.8 billion of that will be on research and development (R&D) and the remainder on associated activities. The federal government is directly responsible for conducting approximately $2.1 billion worth of R&D; the remaining $3.7 billion worth of research is conducted in private firms, universities and non-governmental labs (Statistics Canada, 2005).

The structure of the paper is as follows: Section 2 gives a short introduction as to why governments intervene in the markets for research and development and innovation; Section 3 discusses the nature of five Canadian government programs; Section 4 details the current data situation for each program. Since the situation is not optimal for the measurement and evaluation of the programs, Section 5 asks "Where to Go From Here?". Finally, Section 6 concludes the paper.

2. Rationale for government intervention in research and development

This section is a brief summary of the economic rationale for government intervention in the market for research and development. In an influential paper Schmookler (1959) argued that private firms engage in too little research and development from

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[1] The views expressed in this paper are solely those of the author and do not represent the views of the Government of Canada and/or Industry Canada.

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Table 1
Characteristics of R&D/Innovation

Characteristic	Explanation	Example
Uncertainty	Innovation involves the generation of new ideas, and the development of new markets. The probability of a "success" is therefore low.	When Xerox first invented the photocopier, it did not sell well. The market did not understand its novel uses.
Path-dependency	Technology evolves according to specific paths; the choice of one path may block or delay access to another; this constitutes a risk to the innovator.	MS Windows dominates the desktop operating systems market (over Mac OS and Linux) because it gained an early lead and was able to exploit it. It would be very difficult for another operating system to displace Windows.
Cumulativeness	There is a cumulative property to learning in general. This characteristic is related to absorptive capacity.	Computer programming has advanced because new programming languages build on their predecessors.
Irreversibility	The choice of one technological path often precludes the later choice of alternate paths. This constitutes a risk to the innovator.	VHS vs. Betamax, steam vs. diesel power. An open vs. a closed standard such as Linux vs. Windows
Technological inter-relatedness	Technology is often embedded in systems, with one type of technology dependent on another. This characteristic is related to absorptive capacity.	Computer networks constitute a complex relationship between hardware and software components which must be compatible with one another.
Tacitness	Knowledge is difficult to express clearly and thus, hard to transfer. This characteristic is related to absorptive capacity.	Consulting methodology is hard to codify. Because this knowledge is so tacit, it is expensive and difficult to replicate.
Inappropriability	Environmental factors affect the innovator's ability to capture the profits from the innovation. This constitutes a risk to the innovator.	Pharmaceutical firms can appropriate the returns from drug innovations because patents are effective. Most industries do not obtain the same protection from patents as their products are not as well defined (i.e. by a chemical formula).

Source: Adapted from Teece (1996) and Cohen and Levinthal (1990).

a socially optimal standpoint. His arguments for government intervention included—high costs, prospective returns are too distant and uncertain and that appropriability is weak (Nelson, 1959). Firms will under-invest in research in a competitive economy because the returns cannot be fully captured (due to spillovers). Economic theory predicts that spillovers will distort firms' investment behaviour and thus R&D investment will be suboptimal (Dixit and Stiglitz, 1977; Hall, 1986; Stoneman, 1987).

Yet, the spillover of information is just one facet of the R&D/innovation process. Teece (1996) listed the following additional characteristics in addition to spillovers (inappropriablility): uncertainty, path dependency, cumulativeness, irreversibilities, technological inter-relatedness, tacitness. By its very definition, innovation is uncertain, since it involves the generation of new ideas, and the development of new markets. The three types of uncertainty related to innovation are 'primary', due to randomness; 'secondary', due to communication; 'behavioural', due to opportunism. Primary uncertainty is due to nature and so is not controllable. Secondary uncertainty can be controlled through organizational form. Behavioural uncertainty cannot be controlled per se, but can be mitigated when the proper incentives for management and legal restrictions for competitors are put in place; Path dependency relates to technological trajectories, meaning that technology evolves according to where it has been (the cumulative nature of innovation is tied to the cumulative property of learning in general). Choosing one technology may block or delay access to alternate paths. Furthermore, when a path is taken it generates its own inertia causing 'lock-in effects'. This leads to irreversibility since the choice of one path often precludes the later choice of alternate paths.

Technological inter-relatedness refers to the fact that technology is often involved in systems, with one type of technology often dependent on another. For instance, an 'autonomous innovation' fits into existing systems—a faster microprocessor using the same Intel x86 architecture. On the other hand, a 'systemic innovation' requires that the whole system changes—the replacement of portable CD players with portable mp3 players. Complementary assets are another example of how technological inter-relatedness affects innovation. Complementary assets can be either generic (assets which do not need to be tailored), specialized (unilateral dependence between the innovation and the assets) or co-specialized (bilateral dependence between the innovation and the assets) (Teece, 1986). Tacitness characterizes the knowledge used to develop innovations. Such knowledge is difficult to express clearly and, thus, hard to transfer. The inappropriability characteristic defines the extent to which "environmental factors, excluding firm and market structure, govern the innovator's ability to capture the profits generated by an innovation" (Teece, 1986). All the foregoing is summarized in Table 1.

Uncertainty: The uncertain nature of the innovation process manifests itself in many ways and presents many different hazards to potential innovating firms. Firms are uncertain as to whether they are duplicating the efforts of other innovating firms; let alone the uncertain nature of the innovation process itself (in terms of time lags, cost over runs, loss of key scientific personnel, and outright failure). Either way, the sunk costs of R&D are borne by the losing firms when another wins the race to be first. This presents financial risks for the firm, and managers must determine if the firm can avoid bankruptcy if the outcome is not favourable. Government intervention in the market for R&D is advisable under these circumstances.

Path dependence/cumulativeness/irreversibility and technological inter-relatedness: Path dependency, the cumulative nature of knowledge and irreversibility of historical decision-making help to funnel innovations into an industry-wide standard. Standards are normally viewed as a good thing in an industry, but they also serve to protect the status quo. There are substantial risks to the innovator who deviates from the locked-in design. Witness the 100 year dominance of the internal combustion engine fuelled with gasoline. Thus government intervention is warranted under these circumstances.

An autonomous innovation is easier to market because it fits in an already extant system. A systemic innovation is harder to develop and market because the whole system embodying it is different. Thus systemic innovations are more risky and less likely to be pursued by firms. Government intervention through R&D programs can help to mitigate the risks associated with systemic innovations. Path dependence is associated with first-mover advantage in an imperfect market with imperfect agents (Mueller, 1997), while technological inter-relatedness is an invitation to first-mover advantage by inventing a new widget to fit into the system.

Tacitness: The path to a successful innovation is not trivial. Tacit knowledge (of production processes that work only through experimentation for example) means that it is hard to duplicate what others have already done. Once an innovation occurs it can still be hard for others to catch up (despite spillovers). Yet, innovation presents a double edged sword—it is expensive and risky, yet as Cohen and Levinthal (1990) have shown—firms often require an R&D unit to enhance their absorptive capacity (the ability to learn and incorporate new innovations into their own systems). Tacit knowledge makes the innovation process more expensive, more risky for the firm, reduces the probability of success and makes R&D less attractive. For this reason government intervention is warranted.

Inappropriability: Spillovers consist of the ''involuntary leakage or voluntary exchange of useful technological information'' (De Bondt, 1996). Spillovers can occur within firms, between firms in the same industry, between firms in different industries, and between countries (Finance Canada, 1997). In general, intra-industry spillovers are more common than inter-industry spillovers (De Bondt, 1996). Spillovers have a ''structural component'', and differ according to their domain whether it is the firm, industry, country, etc… (De Bondt, 1996). They occur as a side effect of the innovation process.

Furthermore, spillovers can arise wherever there is an information relation. A firm experiences information relations with four components of its environment: markets, government, the scientific community, and a mediating system. These four systems act on the firm and interact with each other creating a negative effect on innovation. Information relations are asymmetrical, in that the sender possesses more information than the recipient (Hauschildt, 1992). This has two implications for innovation: the first is that spillovers increase the rate of diffusion; the second, and more detrimental problem for the innovator, is that spillovers decrease the appropriability of an innovation. Firms will then be less likely to undertake R&D since they cannot recover their full investment costs. Intellectual property laws (patents) attempt to minimize spillovers in the hopes of increasing the incentive to innovate. Patents, however, offer imperfect protection to innovations. The result is that actual R&D falls short of the socially optimal level and government intervention is warranted.

Finally, Nelson (1959) pointed out that if we consider basic R&D to be a homogeneous good (it is the same whether conducted in the private [for profit] or public sector [not-for-profit]), and if we assume that the marginal cost of research is the same for both types of organizations, then the fact that private firms conduct any R&D is evidence that not enough is being conducted within the public sector. The argument essentially says that if private firms could offload basic research on the public sector they would—because they are unable to appropriate all the returns. It is not surprising then, to see that governments have been funding and continue to fund R&D these past 50 years.

3. Canadian government programs

This section describes the five programs under investigation in this paper and also provides the rationale for government intervention. The intention is not to be exhaustive, but to highlight the budget, key goals of each program, the expected outputs and the overall expected outcome for Canadian society.

Technology partnerships Canada (TPC): Since 1996, Technology Partnerships Canada has been geared towards helping Canadian companies execute R&D that brings new technology closer to the marketplace. As a technology investment fund, TPC hopes to increase economic growth, create jobs, and establish sustainable development. TPC invests in quality research and targets industries such as small and medium-sized businesses that are involved in many different types of technology. TPC is an enabling program in that it is designed to help firms conduct R&D or develop new technologies and/or innovations. Projects must meet certain eligibility requirements: the project meets strategic objectives of the department (social benefits, benefits to recipients and industry, jobs, environmental benefits, repayment), that it is technologically realistic and that the firm possesses the appropriate engineering, managerial and financial resources, that TPC is required for the project to proceed (a test for incrementality, although TPC assistance does not usually exceed one-third of the forecasted costs), and finally that the contribution will be repaid. Payments are negotiated on an individual basis. Non-payment occurs when the project does not meet *a priori* negotiated levels of success (TPC, 2006).

In 1998 the National Research Council took over administration of TPC for SMEs (firms with fewer than 500 employees). This program is denoted as IRAP-TPC. Typical projects under IRAP-TPC are less than $500,000; however, total eligible project costs cannot exceed $3 million. If project costs exceed $3 million, firms are referred to TPC.

As of December 31, 2004, TPC funded 673 projects, which represent a total investment of over $2.7 billion, $1.97 billion of which had been disbursed. Out of these projects, 89% target small to medium-sized companies across Canada. On September 20, 2005 the government announced that TPC and IRAP-TPC would be wound down. The official date for the program's closure is December 31, 2006. It is expected that a new program will take TPC's place, however, at the time of writing no announcement has been made.

Technology Partnerships Canada funds a portfolio of private R&D projects, of which 90% are held by SMEs. SMEs face intrinsic problems because of their small size—capital and liquidity constraints, unproven track record, and relatively low levels of absorptive capacity. For instance, TPC has an aerospace component that funds very large-scale projects. Aerospace projects are inherently risky (Nelson, 1961), path dependent, cumulative, irreversible, inter-related and tacit. A failed large-scale project could easily spell bankruptcy for the firm. For these reasons, government intervention is warranted. The only difference between TPC and IRAP-TPC is that the latter funds small projects of less than $500,000. Again, the program targets SMEs.

Industrial Research Assistance Pro gram (IRAP): The National Research Council's Industrial Research Assistance Program (NRC-IRAP) was created in 1961 to ''stimulate a build-up of competent research teams in industry'' by funding ''long-term applied research projects in science and engineering…for achieving major advances'' (NRC, 1969). IRAP was initially part of a suite of government programs such as the Defence Industrial Research Program (sponsored by DND), the Defence Industry Productivity Program and the Program for the Advancement of Industrial Technology which were both sponsored by Industry, Trade and Commerce (Tarasofsky, 1984). IRAP is the only program of these that remains in operation today.

IRAP is primarily aimed at small and medium-sized Canadian enterprises (SMEs). IRAP provides Canadian SMEs with valuable technological and business advice, financial assistance, and many more types of innovation assistance. Through technological innovation, NRC-IRAP's mandate is to generate wealth for Canada. This is accomplished by their assistance to SMEs through technology and innovation. Strategic objectives are: ''to increase the innovative capacity of Canadian SMEs'' and ''become the national enabler of technological innovation for Canadian SMEs''. Four programs currently embody IRAP's mandate: IRAP-H is a student program providing contributions to firms who employ undergraduates, IRAP-L provides contributions to laboratory investigations, however, funds are less than $4000, IRAP-M funds small R&D projects of less than $25,000 while IRAP-M+ funds R&D projects up to $100,000.[3]

NRC-IRAP's annual budget is approximately $150 million, of which $64.5 million is slated for Non-Repayable Contributions for R&D Activities, $30 million is for IRAP-Technology Partnership Canada, $24 million is for Contributions to IRAP Network Members, $22.5 million pays for IRAP's operations and salaries and the remainder is for the Canadian Technology Network and youth initiatives (NRC, 2002). IRAP's Technological and Advisory Services employs 256 Industrial Technology Advisors with 90 bases of operation throughout Canada.

Like TPC, IRAP targets SMEs. The stated objective of IRAP is to focus on commercializing R&D. The development and commercialization phase is often the most capital intensive portion of the innovation process. It is also inherently risky. Because of this uncertainty, if a firm doesn't win (being first to the market) and the risk is borne entirely by that firm, bankruptcy could result if the outcome was unfavourable.

Atlantic Canada Opportunities Agency (ACOA): Atlantic Canada Opportunities Agency is responsible for administering eight key programs: Atlantic Investment Partnership, Business Development Program, International Business Development Agreement, Seed Capital ConneXion Program, Community Business Development Corporations, Canada Business Service Centres, Regional Economic Development Organizations, and Tourism Development. The *Atlantic Investment Partnership* administers the following four sub-programs: Atlantic Innovation Fund, Atlantic Trade and Investment Partnership, Entrepreneurship and Business Skills Development Partnership, and the Strategic Community Investment Fund. The Atlantic Innovation Fund promotes stronger linkages between universities, and between universities and the private sector. The program supports research in information technology, aquaculture, offshore oil and gas technologies, and life sciences. The Atlantic Trade and Investment Partnership is designed to help firms reach export markets through trade missions, export strategies, education and internships. The program also tries to encourage foreign investment in Atlantic Canada. The Entrepreneurship and Business Skills Development Partnership has three key components: to help develop skills in the workplace (through the Innovation Skills Development Initiative); to encourage women to start their own businesses (through the Women in Business Initiative); to mentor young adults from 15–29 in terms of business skills and to provide assistance with starting their own businesses. The Strategic Community Investment Fund is an infrastructure development program aimed at towns and cities. The goal is to assist communities in developing their industrial base and adopt new technologies.[4] These programs are summarized in Table 2.

Table 2
Innovation programs administered by ACOA

	Budget 2005/2006 (million)	Duration (years)
Total budget for ACOA	$708	5
Atlantic investment partnership	Unknown	5
(1) Atlantic innovation fund[a]	$300	5
(2) Atlantic trade and investment partnership	35.1[b]	5
(3) Entrepreneurship and business skills development partnership	34.6	5
(4) Strategic community investment fund	Unknown	5

Source: Atlantic Canada opportunities agency (2005).
[a] AIF is the only sub-program of the Atlantic Investment Partnership that addressed R&D.
[b] This estimate includes $27.3 million for trade and $7.8 million for foreign direct investment.

The Atlantic region of Canada suffers from a number of handicaps that have hindered development: geographical isolation (remote from Canadian and US consumers, suppliers and world renowned high-technology universities), underdeveloped infrastructure, skilled labour shortages, lack of synergies (no clusters of high-technology industries) and heightened innovation uncertainty (due to all the aforementioned things) to name a few. These characteristics highlight the region's relatively low absorptive capacity which makes the funding of innovation unattractive to venture capitalists and banks. ACOA's Atlantic Innovation Fund fills the private funding gap, increases innovation and aids in economic development.

Canadian Space Agency (CSA): The legislation that enacted the Canadian Space Agency in 1989 was called the Canadian Space Agency Act. The Act specifies: "The objects of the Agency are to promote the peaceful use and development of space, to advance the knowledge of space through science and to ensure that space science and technology provide social and economic benefits for Canadians" (Canadian Space Agency Act, 1990). The agency is governed by a president who has the same powers as a deputy minister (he/she reports directly to the Minister of Industry). The agency has five core missions: Space Programs, Space Technologies, Space Science, Canadian Astronaut Office and Space Operations. The goals of CSA in terms of outcomes for Canadians include economic benefits derived from: new technologies created by world-class research, the diffusion of new technologies, and the education of scientists. It is also expected that the CSA will help Canadians understand sustainable development and in an overall way contribute to their quality of life (TBS, 2002).

The CSA's Space Science Program receives proposals from researchers in universities, research organizations and industries across the country. These are most often in response to Announcements of Opportunities or Requests for Proposals regarding experiments or instrumentation within specific programs. Unsolicited proposals are also considered. Once a proposal has been accepted, the researcher(s) receive both financial and

[3] According to Cooper (2003) historically, there were three other programs IRAP-P funded large projects and was the original Ottawa-based program from 1962; PILP was the Project Industry Laboratory Program that assisted in technology transfer from government and later universities. This program became IRAP-R; IRAP-R funded projects that required university or government technology collaboration or transfer or both. IRAP-R ran from 1984–1994 and was administered in Ottawa.

[4] The *Business Development Program* provides financial assistance to SMEs. It also provides start-up funds, expansion funds, and funds for new capital acquisition. The loans are interest free and unsecured, but still repayable. In the last fiscal year, the Business Development Program provided approximately $18 million in R&D funding (Beeston, 2006). The *International Business Development Agreement* provides trade assistance for SMEs to help them enter international markets. This program is run in cooperation with Industry Canada, Department of Foreign Affairs and International Trade and the provincial governments of New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland. The *Seed Capital ConneXion Program* for Young Entrepreneurs targets entrepreneurs under 30 years

(*footnote continued*)
of age. The program provides special counselling and training to help find capital. *Community Business Development Corporations* are composed of 41 not-for-profits to provide financial services and advice to the private sector. ACOA manages *Canada Business Service Centres* which provide information to entrepreneurs on government programs, services and regulations. ACOA provides funding for 52 *Regional Economic Development Organizations*. These organizations help municipalities partner with the federal/provincial governments and stakeholders. The Tourism Atlantic Branch of ACOA administers *Tourism Development*. The program tries to increase the profile of Atlantic Canada through international advertising geared towards the US, Japan and Europe.

managerial assistance from the Space Science Program.[5] The program's mandate includes (TBS, 2002):

- Technology development.
- Partner with industry for commercial success.
- Increase the number of SMEs engaged in space research.
- Enhance regional development through targeted grants.
- Increase cooperation between civilian and defence related space research.
- To increase public awareness and appreciation of space, and science and technology in general.

National Defence: Defence R&D Canada (DRDC) is an agency of the Canadian Department of National Defence with an annual budget of $300 million. Defence R&D Canada operates six research centres across the country–Suffield, Toronto, Ottawa, Valcartier, Atlantic, Centre for Operational Research and Analysis. The mission of DRDC is to conduct R&D for new defence capabilities by collaborating with academia and industry, to forecast and advise on new technological trends, to diffuse new technologies to customers and to offer scientific advice to DND. DRDC administers two major programs: Applied Research Program and Technology Demonstration Program.

The Applied Research Program involves 600 government R&D scientists working on more than 80 projects. Typical project time frames are five years, with costs of $3 to $6 million. Three sub-programs are administered by the Applied Research Program: the Defence Industrial Research Program provides financial and scientific support to Canadian firms developing defence related technology; DND/NSERC Research Partnership Program endeavours to build linkages between researchers in DND, universities and the private sector, to transfer research results and technology to the public and private sectors. Grants for this program are awarded to university-based researchers. They are expected to collaborate with DND and Canadian-based companies (who must provide funding as well). Projects are supported for up to five years with a maximum budget of $500,000; Defence Communications Program is a joint collaboration between DND and Industry Canada's Communications Research Centre which has four areas of focus—terrestrial wireless technology, satellite communications and radio propagation, broadcast technology and broadband network technologies.

The Technology Demonstration Program is designed to exhibit new technologies developed internally by DRDC and by industry to government and the military. Since development costs for new products can often be prohibitive this program allows new technologies to be evaluated without having to fully complete this stage of the innovation process. The result is a savings in time and expenditure. Thus the program helps to develop the concept and evaluate new technologies for their possible future role within the military in a cost efficient and timely manner.

With respect to defence (DRDC) and the space program (CSA) the sole purchaser of these activities/outputs is the Federal government. Defence and space research is inherently uncertain, path-dependent, cumulative, inter-related and irreversible. Furthermore, the application of the new technology can be very limited (i.e. a sole purpose technology) and assets are specific (sunk costs are high). Thus, it is only reasonable to expect the Federal government to fund such activities since it has the primary responsibility for national defence and the space program. In other words, the space and defence programs are "public goods" that benefit all Canadians.

Table 3 summarizes the five government programs/agencies under investigation in this paper (note that only one of the five is a "program" per se—IRAP; TPC, CSA and DND are special operating agencies within their home departments, while ACOA is considered as an autonomous agency comprising its own Federal department). Of the five, only two have a limited lifespan (i.e. funding is not guaranteed for program continuance; the Federal Government allocates funds formally in the budget): Technology Partnerships Canada and Atlantic Canada Opportunities Agency.

- The survey includes the following government program expenditures: Canadian Federal Government R&D grants, Industry Canada—Defence Industry Productivity Program, Industry Canada—Technology Partnerships Program, National Research Council—Industrial Research Assistance Program, other grant programs.
- Economic variables in the R&D survey: revenue, percent of revenue generated by new or substantially improved products/services by the firm in the previous three-year period, number and education of scientists and engineers (Bachelors, Masters, Doctoral), expenditures for R&D broken down by: wages and salaries, other current costs, capital expenditures including land, buildings, equipment and other.

4. Data availability for the five programs[6]

Measurement of the impact of R&D programs can be approached from different perspectives. The following is a brief list of some proposed methods: science and technology indicators (Godin, 1996), overall methods of evaluating publicly funded R&D (Arnold and Balazs, 1998; Geisler, 1994; Kostoff, 1996), economic methods concerned with evaluating public R&D (Cozzarin, 2006; David, Hall, and Toole, 2000; Link, 1996; Lipsey and Carlaw, 1998; McFetridge, 1995; Salter and Martin, 2001; Tassey, 1999, 2003), and the use of bibliometric methods (Gauthier, 1998; Narin and Hamilton, 1996; van Leeuwen, van der Wurff, and van Raan, 2001). The main stumbling block for the implementation of any method is data availability. So before moving forward, the current situation needs to be assessed. Below is a summary of data that are currently available for the five government agencies/programs. In general, data availability on R&D outcomes are nonexistent, except for TPC and IRAP-TPC. This will be discussed in more detail in the section to follow.

Technology Partnerships Canada (TPC): TPC appears to be the only R&D program of the five, with readily available data by firm on program expenditures. The data from TPC (2006) span 210 firms and 913 TPC projects from 1996 to 2005. Data are by NAICS industry group distributed across 27 industries, 11 of which are in manufacturing. Since many of the firms are traded on the stock exchange, it would be possible to link TPC project expenditures to financial data on the firm from the System for Electronic Document Analysis and Retrieval (SEDAR, 2006). Firms and investment funds listed on the stock market can file securities related documents electronically using the database which is

[5] The Space Science Program is composed of six advisory committees representing Space Environment, Atmospheric Environment, Space Astronomy, Space Exploration, Microgravity Sciences and Space Life Sciences. The committees make recommendations and provide advice on research priorities and selection procedures for funding projects.

[6] Statistics Canada's (2004) R&D survey called "Research and Development in Canadian Industry" is a multi-year ongoing survey of Canada's R&D performing firms. Initially, it was felt that this survey would be a good starting point for an economic assessment of government R&D spending. Relevant variables from the survey include: ****Unfortunately, the sample size by industry is small, with some major firms doing a large percentage of all R&D performed in a single industry. Because of confidentiality issues Statistics Canada will not release these data for analysis.

Table 3
Government program summary

Program/ Department/ Agency	Institutional affiliation (governance mechanism)	Inception date	End date	Total budget ($mil.)	Annual budget ($mil.)	Mandate and goals
Technology Partnerships Canada	Special operating agency of Industry Canada	1996	Dec. 31, 2006	2700	–	• to increase economic growth, create jobs, and establish sustainable development • is an enabling program designed to help firms conduct R&D or develop new technologies and/ or innovations • targets SMEs
Industrial Research Assistance Program	National research council	1961	None	On-going	150	• stimulate wealth creation in Canada through innovation in SMEs • increase innovation capacity of SMEs • focus on commercializing publicly funded R&D (collaboration between SMEs and research organizations)
Atlantic Canada Opportunities Agency	Autonomous agency composing its own Federal department	1987	None	708 (over five years)	142	• economic development of Atlantic Canada by reducing risks or costs faced by the private sector so that investment is enhanced • emphasis on SMEs
Canadian Space Agency	Special operating agency of Industry Canada	1989	None	On-going	350[a]	• the Canadian Space Program develops and applies space science • advances scientific knowledge of space • to develop a competitive Canadian space industry
Defence R&D Canada	Special operating agency of National Defence	WW I	None	On-going	300[a]	• conduct R&D for new defence capabilities by collaborating with academia and industry • two main programs: Applied Research Program, Technology Demonstration Program (see text for details)

[a] *Source*: Budget 2005 (http://www.fin.gc.ca/access/budinfoe.html).

administered by the Canadian Securities Administrators (each province and territory has its own securities regulator, for a total of 13 in Canada). By combining TPC expenditure data with firm-level financial data it would be possible to estimate a productivity equation for the program. It would be possible to discern by how much productivity has increased with the addition of TPC funding. However, this method would be a rough approximation of the effects of the program.

Industrial Research Assistance Program (IRAP): For the fiscal year 2004–2005 IRAP funded 2615 projects with $80.2 million of funding. The funding data are available for NAICS industries. However, the current data do not disaggregate funding to the level of IRAP-H, IRAP-L, IRAP-M or IRAP-M+. It is likely that such data are available from IRAP, it is just that they were not supplied to us.

Data on program expenditures for IRAP are spotty at best. According to Cooper (2003) the following data are available: 1967–1970 (4 years), 1973 (1 year), 1982–1984 (3 years), 1986 (1 year), 1988–1989 (2 years), 1992–1995 (4 years), 1997 (1 year), 2000 (1 year) and 2004–2005 (2 years). Given the sparseness of the data, it would not be possible to conduct an econometric study.

Atlantic Canada Opportunities Agency (ACOA): Atlantic Innovation Fund expenditures are available for 13 NAICS (3-digit) industries from 2003 to 2006. Firms who receive AIF funding are required to reimburse the program if their project is successful. Not-for-profit organizations are not required to repay AIF. Since AIF closely resembles Industry Canada's TPC program, the administrators should be able to provide project outcome data (i.e. for individual projects there should be an associated "outcome" where the program was reimbursed, the level of reimbursement or whether the project was a failure).

Table 4
CSA Contracts awarded over $10,000

Fiscal year and quarter	Number of contracts	Contract expenditure ($ mil.)	Fiscal year and quarter	Number of contracts	Contract expenditure ($ mil.)
2004–2005			2005–2006		
Q1	138	10.032	Q1	106	37.545
Q2	110	25.621	Q2	96	19.942
Q3	155	21.498	Q3	145	28.331
Q4	348	36.846	Q4	212	34.188
Total	751	93.998	Total	559	120.007

Canadian Space Agency (CSA): On March 23, 2004, the government announced a new policy on the mandatory publication of contracts over $10,000. These data are published on CSA's website (http://www.space.gc.ca/asc/eng/resources/publications/contracts.asp) and are summarized in Table 4. Program expenditures for the Canadian Space Agency are reported using 518 "Material Groups" not NAICS. There does not seem to be a concordance between the Material Groups provided by CSA (2006) and the Canadian Space Agency proactive disclosure of contracts over $10,000.

National Defence: On March 23, 2004, the government announced a new policy on the mandatory publication of contracts over $10,000. These data are published on DND's website (http://www.admfincs.forces.gc.ca/daip/contracts/reports_e.asp) and are summarized below in Table 5. Program expenditures are grouped into what appear to be idiosyncratic descriptions. There may be a concordance table for the DND nomenclature and NAICS, however, this information is unknown to the author.

4.1. Summary of current data

Below in Table 6 the current data situation is summarized. Only TPC and IRAP-TPC collect information as to whether the initial funds from the government were repaid. It would be possible to conduct a firm-level econometric study of TFP growth and a firm-level econometric study of spillovers using the TPC, IRAP-TPC data. No other analysis (such as NPV, IRR, benefit–cost, social welfare or bibliometric) could be performed with the current data. IRAP and ACOA (Atlantic Innovation Fund) have data amenable to an industry-level econometric study of TFP growth and to an industry-level econometric study of spillovers. In order to conduct such analyses at least ten years of time-series data would be required. No other analysis could be performed with these data. Data from the Canadian Space Agency and DND's Defence R&D Canada could be used to conduct an industry-level econometric study of TFP growth, and an industry-level econometric study of spillovers. Again, at least ten years of time-series data would be required, with the further restriction that non-R&D expenditures would have to be cleansed from the data. No other analyses could be conducted with the data.

It is unfortunate, that other outcome *data per se* seem to be unavailable. As a reviewer pointed out, both the Advanced Technology Program and Small Business Innovation Research program both have well-developed metrics for evaluation. These additional metrics are flagged below in Table 7. Departments may very well collect other output and outcome indicators, but they are neither in their publications nor in their websites. This serious concern is addressed in the next section. Joint ventures seem to be possible within two agencies: CSA and DND. Because of their dual private-public nature, these hybrid projects would require special treatment especially in terms of R&D outputs.

Table 5
DND contracts awarded over $10,000

Fiscal year and quarter	Number of contracts	Contract expenditure ($ mil.)	Fiscal year and quarter	Number of contracts	Contract expenditure ($ mil.)
2004–2005			2005–2006		
Q1	1517	424.4	Q1	1626	1,313.2
Q2	1925	728.5	Q2	2303	512.1
Q3	1980	5,933.6	Q3	2429	2,881.5
Q4	3718	790.9	Q4	676	93.9
Total	9140	7877.4	Total	7034	4800.7

Table 6
Summary of data availability for the five programs/agencies

	TPC	IRAP	ACOA	CSA	DND
Type of program[a]	• private R&D	• private R&D	• private and public R&D together (joint venture)	• private R&D in the form of contracts - public R&D performed by in-house R&D labs	• private R&D in the form of contracts • public R&D performed by in-house R&D labs
Program restrictions	• R&D funding repayable if successful	• for IRAP-TPC R&D funding repayable if successful (projects < $300k) • for R&D activities program contributions are non-repayable	• Atlantic Innovation Fund provides funding for university and private sector R&D collaboration	• R&D work completed under contract	• R&D work completed under contract
Program funding data	• time series by firm and categorized by NAICS	• time series by industry categorized by SIC and NAICS • IRAP-TPC data were not collected	• by industry categorized by NAICS • time series availability?	• by firm categorized by material groups • time series availability?	• by firm categorized by DND's own system • time series availability?
Program outcome data	• repayment or non-repayment is tracked • other information is not collected	• repayment or non-repayment is tracked for IRAP-TPC • other information is not collected	• not collected	• not collected	• not collected
Possible analysis with current data	• firm-level econometric study of TFP growth • firm-level econometric study of spillovers	• industry-level econometric study of TFP growth • industry-level econometric study of spillovers • at least 10 years time-series data required	• industry-level econometric study of TFP growth • industry-level econometric study of spillovers • at least 10 years time-series data required	• industry-level econometric study of TFP growth • industry-level econometric study of spillovers • at least 10 years time-series data required • non-R&D expenditures would have to be cleansed from the data	• industry-level econometric study of TFP growth • industry-level econometric study of spillovers • at least 10 years time-series data required • non-R&D expenditures would have to be cleansed from the data

[a] A relevant question to ask regarding the type of program: are there any joint ventures between CSA and/or DND labs and private R&D labs? The answer to this question is unknown to the author.

Table 7
Data Requirements for R&D Assessment

	Private R&D [TPC, IRAP-TPC, IRAP, AIF]	Public R&D [DRDC, CSA]
General variables		
Incrementality	• would this project have been undertaken in the absence of government funding? • if so what would the investment costs have been (in dollars)?	
Size	• firm sales in beginning and ending years of project • total number of R&D scientists	• total number of R&D scientists
Shares	• if firm's shares traded on the stock exchange, value of stock at start of project, value at end of project	
Market value	• number of shares outstanding at start of project, at end of project	
R&D inputs		
Program funding	• by year from start to finish	• by year from start to finish
Funding restrictions	• was the project funding organization reimbursed for its contribution? • if not, why not?	
Project costs	• costs of R&D project (interest on loans, equipment costs, labour/personnel costs) borne by your institution by year over the course of the project	• costs of R&D project (PY's, equipment) borne by your institution by year over the course of the project
Efficiency of investment		• is the public investment in this research more efficient than private investment? • what are the additional costs the private sector would have had to incur to produce the same technology? • compare the costs avoided by the private sector to the costs incurred by the public sector to determine IRR, benefit-cost ratios • this is an indirect method of evaluation of public institutions/programs • see Link and Scott (1998, 2005)
R&D Outputs		
Revenue[a]	• actual revenue stream associated with commercialized innovations	• actual revenue stream associated with commercialized innovations (by private firms using the knowledge as a spillover)
Percentage of Successful Projects[a]	• percentage of projects that lead to one or more commercialized innovations–or are brought from one stage of the innovation process to another	
Percentage of Successful Companies[a]	• percentage of companies participating in the program still conducting research/still incorporated five-plus years after the project is completed	
Publications	• complete bibliographic citations for all technical papers published in journals, conference proceedings or elsewhere	• complete bibliographic citations for all technical papers published in journals, conference proceedings or elsewhere
Presentations	• number of professional presentations given outside of home institution • to what kinds of groups?	• number of professional presentations given outside of home institution • to what kinds of groups?
Timeframe for R&D	• as a result of this funding, are you ahead/in the same place/behind in achieving similar goals and milestones? • if ahead, by approximately how many months?	• as a result of this funding, are you ahead/in the same place/behind in achieving similar goals and milestones? • if ahead, by approximately how many months?
Scope of R&D	• because of government funding was your project broader in scope than it otherwise would have been? • did it help initiate a new research direction and expand your lab's competencies in new areas?	• because of government funding was your project broader in scope than it otherwise would have been? • did it help initiate a new research direction and expand your lab's competencies in new areas?
Technical nature of R&D	• because of government funding is the project more technically challenging?	• because of government funding is the project more technically challenging?
Duration of research	• is the expected duration/time to completion longer/the same/shorter?	• is the expected duration/time to completion longer/the same/shorter?

Table 7 (*continued*)

	Private R&D [TPC, IRAP-TPC, IRAP, AIF]	Public R&D [DRDC, CSA]
Product innovation	• number of new or significantly improved products introduced into market • date of product introduction to market • expected revenue generated by year in dollars (up to foreseeable future)	• number of new or significantly improved products • expected industry effects by year (up to foreseeable future)
Patents	• number of patents • complete citations for patents • patent linkage studies to identify how publications/patents associated with a project are subsequently cited by other patents/ companies[a] • patents/patent citations are being used as one way to identify "innovation hotspots", a concept that may be of value in programs focusing on specific sectors[a]	• number of patents • complete citations for patents • patent linkage studies to identify how publications/patents associated with a project are subsequently cited by other patents/companies[a] • patents/patent citations are being used as one way to identify "innovation hotspots", a concept that may be of value in programs focusing on specific sectors[a]
Process innovation	• number of new or significantly improved processes put into practice • date when process was incorporated into your operation • expected cost savings by year in dollars	• number of new or significantly improved processes • expected industry effects by year
Standards		• did the project lead to new standards, measurement technology, or new databases? • if so, which of these is relevant?

[a] These metrics are currently used by the Advanced Technology Program and the Small Business Innovation program in the United States. Thanks to the reviewer who provided this information.

5. Where to go from here?

5.1. Proposed course of action

The mandate and goals of programs may or may not lead to easily measured outcomes. Here the outcome is meant to be the ultimate effect of the program on the firm's profits/ employment/sales growth or the economy in general. It should be relatively clear to the reader by now, that measurement of any outcomes related to government sponsored research, development, commercialization, infrastructure etc. should be multidimensional; thus the measurement process will be time-consuming, expensive (in terms of data collection) and fraught with methodological pitfalls. This is borne out by the testimonials of Rank and Williams (1999) who analyzed Canadian Networks of Centres of Excellence and by Lipsey and Carlaw (1998) in their analysis of the Defence Industry Productivity Program, four programs designed to enhance technological change—Industrial Research and Development Incentives Act (enacted 1966), Program for the Advancement of Industrial Technology (enacted 1965), Enterprise Development Program (enacted 1972), Industrial and Regional Development Program (enacted in 1983), and NRC's Industrial Research Assistance Program (enacted 1961).

Public R&D defined as research conducted within a public institution by public employees [where profit is not a motive] tends to be different from private R&D. Typically public R&D has low appropriability but high social payoffs. Furthermore, sunk costs could be prohibitive, the risk of failure could be prohibitive, the technology could have narrow application such as in space and defence related technology, or it could be basic research with potentially wide application to varied industries. For these reasons, government researchers should have different performance metrics than private researchers. As an example, it would be fine to use bibliometrics as an output indicator for DRDC but perhaps less appropriate for TPC, IRAP-TPC, IRAP and AIF since these programs target businesses.[7]

It should be mentioned here that capital markets are imperfect (i.e. transactions costs to raise capital via an IPO are quite substantial) and thus firms are subject to credit limitations. As a result firms are relatively risk averse compared to government since they cannot self-insure for all possible indemnities. Government on the other hand, can self-insure, and for this reason governments rarely declare bankruptcy. As a consequence, it is generally agreed that the private hurdle rate (also called the minimum acceptable rate of return or the weighted average cost of capital) for a firm exceeds the social hurdle rate for the government (Arrow, 1962; Link and Scott, 2005; Nelson, 1959). This means quite simply that firms require a higher payoff than the government to undertake R&D.[8]

The risk profile of any particular project is negatively affected by uncertainty, path-dependency, irreversibility (not only are technologies irreversible but projects are often irreversible in terms of their sunk costs), and inappropriability (Table 1). The four characteristics in concert with one another or individually lower the private rate of return. It may be the case that the private rate of return for a project falls below the firm's hurdle rate.

[7] A reviewer has correctly pointed out that there is no reason necessarily to exclude bibliometrics from assessment of the private research programs—in certain industries (e.g., biotechnology/pharmaceuticals) there may still be value in assessing publication rates and quality of published research.

[8] It would be illogical for a firm to invest in a project that yields a risk-adjusted rate of return (i.e. after performing a sensitivity analysis) that is lower than the firm's hurdle rate. A good way to conceptualize the hurdle rate is to treat it as the weighted average cost of capital (WACC). The WACC is the cost of obtaining capital through equity in the stock market (by selling new shares) or by obtaining capital through borrowing from banks or by obtaining capital through retained earnings. An equation for WACC is: $WACC = \omega_s{*}s{+}\omega_b{*}b{+}\omega_r{*}r$; where s, b and r represent the dollar value of equity shares (stocks), of borrowing and of retained earnings respectively. The sum of the weights (ω_i) must equal one, or more concretely: $\omega_s+\omega_b+\omega_r = 1$.

In such as case, the project will not be undertaken unless some form of government intervention presents itself. Government intervention can help reduce the risk and uncertainty of a given project (since the firm can offload some of the risks onto the government) and therefore raise the private rate of return above the hurdle rate. The relevant question to ask is "Why would the government intervene in order to raise the private rate of return". The answer as to why the social rate of return may exceed the private rate of return is that the innovation is more valuable to society as a whole than to a single individual (for this reason the government would like it to diffuse rapidly). An example of this is medical research, defence research and space research wherein the Federal government is heavily involved in subsidizing private firms and/or performing research itself.

The data requirements for program/agency assessment are placed into two functional categories in Table 8.[9] DRDC and CSA should be placed within the category "public R&D", while TPC, IRAP-TPC, IRAP and ACOA's Atlantic Innovation Fund should be placed within the category "private R&D".[10] In terms of the two public R&D programs—defence (DRDC) and space (CSA) econometric studies using total factor productivity are warranted. Government R&D spending in these two sectors comprises the bulk of expenditures. Furthermore, both industries are well defined and self-contained (i.e. they are not consumer oriented) making the process of measuring the effects of R&D all the easier.[11]

Under the category "General Variables" incrementality, size, share price, market value of the firm and number of full-time R&D scientists are included. Incrementality determines whether the project would have been undertaken in the absence of government funding. The number of R&D scientists will be useful in terms of grouping firms and government institutions by size. Firm sales (another measure for size in private firms), stock prices and number of shares outstanding are not applicable to public institutions. These variables will be useful to ascertain whether the firm has exhibited growth over the course of the project and whether its financial situation has remained static, improved or declined.

Under the category "R&D Inputs" the following are included:

- Program funding—the program funding level by the government is required by year to be used in calculating IRR's, net present values and benefit–cost ratios.
- Funding restrictions—whether the initial funding was repaid or not is a useful and readily available metric for private R&D programs sponsored by TPC or IRAP-TPC; this measure will help to compute failure rates for TPC funded projects which can be compared to publicly available R&D failure rates (published in academic literature).
- Project costs—R&D costs direct and indirect are required by year to be used in calculating IRR's, net present values and benefit–cost ratios.
- Efficiency of investment in public R&D—Link and Scott (1998, 2005) use an alternative approach to compute IRR's, net present values and benefit–cost ratios for public R&D; they call this method "counterfactual evaluation"; Link and Scott assert that the relevant question to ask should be: "is the public investment in this research more efficient than private investment?", to answer the question the additional costs to the private over and above those incurred by the public sector would have to be found, to find the IRR, net present value and benefit–cost ratio the costs avoided by the private sector are treated as benefits and the costs incurred by the public sector are treated as costs.

Under the category "R&D Outputs" the following are included:

- Revenue—actual revenue stream associated with commercialized innovations. ATP currently uses this measure for up to and beyond five years for each project.
- Percentage of successful projects—percentage of projects that lead to one or more commercialized innovations or are brought from one stage of the innovation process to another. ATP currently uses this measure.
- Percentage of successful companies—percentage of companies participating in the program still conducting research/still incorporated five-plus years after the project is completed. ATP currently uses this measure.
- Peer-reviewed publications—is a common bibliometric measure of research output, citation analysis of peer-reviewed publications could be performed using this information
- Presentations—an early measure of research output; this metric should be of more importance to public R&D agencies/programs.
- Timeframe for R&D—whether government funding had an affect on the pace with which the research took place.
- Scope of R&D—determines whether government funding increased the scope of the research that was undertaken.
- Technical nature of R&D—determines whether government funding influenced the technical difficulty of the research.
- Duration of research—determines whether the time to completion of the research was affected by government funding.
- Product innovation—data collected on product innovation is required to compute IRR's, net present values and benefit–cost ratios.

[9] The third category of R&D is a hybrid, wherein the government collaborates with the private sector. This is called an R&D joint venture.

[10] As a reviewer correctly pointed out, AIF has a set of regional economic development goals. The reviewer went on to suggest that evaluation of AIF should have an additional set of research capacity development and regional economic development measures, such as:

- Sustainability of collaborations between industry partner and university post-award.
- Research capacity development by university.
- New hiring in department/area of research.
- Change in departmental ranking/perceived quality of department/university.
- Change in publications by department in particular field—associated with the award and not.
- Change in funding for research in department/area of research (government funds, private-sector funds, etc.).
- Regional economic development (likely as case studies).
- Any new clusters of firms emerging near university spinning out of research undertaken.
- Decisions by industry partner to increase R&D staff locally/build new facilities, increase production locally.

[11] A reviewer has indicated that there are other, potentially simpler, measurement strategies for defence and space programs:

- How large/independent are Canada's space/defence technology companies?
- In which subsectors do they produce components/subassemblies purchased by larger (e.g., EU, US) defence/space firms, while in which do they design, manufacture components, assemble, and field entire vehicles/satellites/weapons systems?
- What is the percentage of content of Canadian-manufactured products/systems that is sourced from suppliers in Canada?
- What percentage of the value of new procurement by Canada's space and defence agencies is sourced from Canadian companies?
- How large is Canada's trade surplus/deficit in these two sectors? With which countries?
- Case studies aiming to assess attribution are a valuable complement, tracing how funds provided through one of the R&D programs led to the development of new technology that was then commercialized.
- Case studies of subsectors where there appear to be spillovers between defence and non-defence R&D (e.g., aerospace).

- Patents—are a common measure of innovation output, however, the economic value of a patent is hard to discern (unless licensing revenue is provided).
- Process innovation—data collected on process innovation is required to compute IRR's, net present values and benefit–cost ratios.
- Standards attributable to the project—this measure should usually relate to public R&D as these programs/agencies may legitimately lead to new standards, new measurement technologies and/or new databases.

A very important question to ask pertaining to Table 7 is this: how will this data be collected? Link and Scott (2005) propose a two pronged approach. The first phase involves sending a survey instrument to all current program participants. The following outputs from the R&D projects should be collected: the scope of the laboratory research (Q1), publications (Q2), patents (Q3), presentations (Q4), other technical outputs (Q5), leveraging of R&D funding (Q6 and Q9), cycle time of R&D (Q10) and the technical nature of R&D (Q11). It should be pointed out that Link and Scott were evaluating the National Institute of Standards and Technology's (NIST) Advanced Technology Program (ATP). ATP is managed within NIST and is designed to provide funding to R&D private R&D projects. However, the ATP statute states that up to ten percent of the programs funds can be awarded on a competitive basis to internal NIST researchers. These internal awards are called "intramural" by NIST. Hence, the survey instrument is designed to collect pertinent information for a public R&D institution. The second phase of the assessment involves in-depth case studies of a small number of projects. It is within these case studies that Link and Scott collect the relevant economic data to calculate IRR's, net present values and benefit–cost ratios.

I would argue that it should be possible to get all the information required for an economic and qualitative assessment through a survey instrument (perhaps a more palatable term is "progress report") designed around Table 7. The survey should be relatively similar across all five programs/agencies with the idiosyncrasies of each program/agency taken into consideration. The survey therefore should be designed in consultation with the public granting agency and the funding recipients. Furthermore, the survey should be administered by the granting agency itself (i.e. not an external agency). The reasons for local administration are that: program participants will want to cooperate with their benefactor, they will be wary of outside assessments masquerading as a means to withdraw program support, they will be wary of outside agencies' ability and/or willingness to keep the data confidential despite their assurances to the contrary.

6. Conclusion

This paper has summarized five Canadian programs directed at R&D and commercialization—Technology Partnerships Canada, Industrial Research Assistance Program, Atlantic Canada Opportunities Agency and its program Atlantic Innovation Fund, Canadian Space Agency and National Defence's R&D agency. The main policy implication is that, while the federal government would like to have concrete assessments of its R&D programs, the extant data are not up to the task.

Thus, the ultimate intention of this exercise is to move towards the measurement of the intrinsic economic value of the five programs. Yet, in order to meet that objective, this paper has (of necessity) been primarily one of fact-finding. At this stage, it is readily apparent that more data are required from the five programs/agencies in order to conduct a thorough economic assessment. Eighteen areas for data collection categorized as general information, R&D inputs or R&D outputs have been put forth. These data range from qualitative to quantitative. The "hard" data will necessarily take the form of financial disclosure, disclosure of project outcomes, costs and revenues. The data can be collected by either a progress report that is sent to all current program participants, by individual visits to a small number of program participants in order to assemble case studies, or by a combination of both techniques. The next logical step is to forward this report to each agency and ask for their cooperation in assembling the data. Full disclosure of what information is collected by each agency will be indispensable for the data assembly phase. Onsite visits by government representatives and outside contractors will most likely be required.

Appendix A

A.1. Canadian program audit and evaluation

Reports that specifically analyzes the five Canadian programs under review in this study will be summarized below. There has been progress since MacDonald (1987) lamented that "Program evaluation, as practiced by the evaluation community, is seldom performed on research and development (R&D) programs…" And only a year before the Comptroller General of Canada—M. Rayner (1986) commented on how on average 100 evaluation studies were undertaken by the Federal Government each year: "The rate of production…is about half the rate we need if virtually all government programs are to be reviewed at least every five years. This slow rate reflects inevitable slippage on studies in the most conscientious departments, and feeble or no effort on the remainder…" Evaluations tend to be broader based than audits—they typically included measures of the program's social and economic benefits. Most programs are subject to periodic audits which tend to concentrate on the mechanisms which govern how public funds are spent. At the risk of oversimplification, auditors primarily look at the "books" and how the organization functions (i.e. an internal exercise), while evaluators primarily examine programs' social and economic outcomes (i.e. an external exercise).

Audits take two forms: internal audits performed by a branch within a federal department or by an independent agency (such as Price Waterhouse, Ernst & Young LLP, etc.), and external audits conducted by the Auditor General. Internal program audits are for the use of management and also to supply evidence to the Comptroller General's Office (housed within the Treasury Board Secretariat) of "value for money" and that due diligence is being exercised with public funds (TBS, 2006). External program audits are conducted by the Auditor General of Canada. Audits of this type tend to be conducted on an *ad hoc* basis since only 30 can be conducted in any given year (OAG, 2006). The Auditor General is completely autonomous, and thus her audits are seen as free of any bias, although the reports dovetail with internal audits, since their purpose is: "…to help hold the government to account for its stewardship of public funds" (OAG, 2006).

Technology Partnerships Canada: In October, 2003 a private consulting firm called Performance Management Network Inc. conducted an evaluation of TPC. The evaluation had five key objectives: program relevance, governance, design and delivery, success and lessons learned. The evaluation was multi-faceted with six primary tasks: review of program files, review of electronic databases on TPC and IRAP-TPC, interviews with management and staff, telephone survey of 99 out of 133 TPC clients, telephone survey of 120 out of 323 IRAP-TPC clients, and finally six case studies were conducted (four of these were for TPC and two were for IRAP-TPC). The findings of the report in terms of relevance, governance, design and delivery are somewhat vague. However, in terms of success the consulting firm's survey results found that 85% of TPC and 89% of IRAP-TPC projects had full or "high" incrementality (Performance Management Network, 2003).

Audit and Evaluation Branch of Industry Canada conducted an internal audit of TPC and IRAP-TPC in 2003.[12] The purpose of the audit was to check: TPC's control mechanisms for selection, approval, payment and review of the program, whether transactions were above board, whether the operation of the program and its administration were efficient, that program terms and conditions (i.e. compliance) were being met by management and clients. The audit was conducted in two phases. Phase one entailed detailed interviews and consultations with management and documentation to understand how the program worked and the inherent risks involved. Phase two entailed the examination of 58 TPC files worth $1.1 billion along with 25 IRAP-TPC files worth $9.9 million. The findings of the audit can be summarized as follows:

- Management practices—good with minor recommendations for improvement.
- Rules and regulations for transactions—full compliance was observed.
- Rules and regulations for clients—full compliance was observed, however, the auditor's recommendation was to have 3rd party examine clients' books when they were not in a position to repay TPC.

IRAP: The following IRAP evaluations have all been quite positive; Task Force on Federal Policies and Programs for Technology Development (1984), the Ministerial Task Force on Program Review (1985), the Report of the Standing Committee on Industry, Science and Technology, Regional and Northern Development (1991), and various reports by the National Advisory Board on Science and Technology (1992, 1994). Unfortunately, these evaluations do not cite tangible economic or financial benefits derived from the program. NRC has evaluated IRAP on a five-year cycle, often using independent consulting firms.

The Policy, Planning and Assessment Directorate of NRC evaluated IRAP in 2002 (NRC, 2002). Programs under investigation included Technological and Advisory Services, Non-Repayable Contributions to SMEs for R&D, Canadian Technology Network. The Pre-commercialization Assistance program was not audited. The audit had four main criteria: whether the program is relevant to SMEs, whether the program meets its objectives, how well the program is delivered to clients, and its level of incrementality.

The audit was comprised of the following procedures: data and document review of the program, interviews with 120 IRAP stakeholders, a survey of 684 clients who obtained IRAP funding within a 1996–2001 timeframe, 26 projects were evaluated using a socio-economic framework, IRAP was compared to six international programs, an "innovation impact" analysis was conducted using an innovation survey. Key findings of the audit are summarized below (all figures relate to the period under investigation from 1996–2001):

- 12,364 IRAP funded projects culminated in 39,186 new/significantly improved products/processes/services, this translates into 3.2 innovations per funded project.
- $4.2 Billion in sales are attributable to IRAP this translates into 11 times IRAP's total project budget.
- Existing innovations due to IRAP are expected to bring $14 billion in future sales.
- The number of jobs directly attributable to IRAP is 12,025.
- World-first innovations attributable to IRAP = 37%.
- Canada-first innovations attributable to IRAP = 66%.
- The present and future value to the federal government in terms of tax revenue was estimated to be 11 times that of the original IRAP program expenditure.

Table A1
Defence R&D expenditures

Cost item	Fiscal Year (April 1–March 31)				
	1996/1997	1997/1998	1998/1999	1999/2000	2004/2005
	($ million)				
Salaries	54.6	53.75	54.5	59.0	88.8
R&D activities	96.5	88.2	86.1	89.5	128.7
Operation and maintenance	17.8	17.7	19.4	20.6	24.7
Capital	9.1	12.8	17.4	39.4	7.5
Miscellaneous	1.1	0.97	0.24	3.2	20.0
Total	179.1	173.4	177.2	211.8	269.7

Source: National Defence (2001, 2004).

ACOA: ACOA program expenditures account for less than 1% of the GDP in Eastern Canada. Thomas and Landry (2000) evaluated the contribution of Atlantic Canada Opportunities Agency to growth and employment in Eastern Canada using multiple criteria. They found that ACOA's impact grew from $1.4 billion in 1992 to $3.7 billion in 1997. One dollar of ACOA expenditure resulted in a five dollar increase in GDP. The unemployment rate in Eastern Canada was 2.8% lower than would be the case without ACOA. The authors also report that ACOA assisted firms have offset the losses of non-ACOA assisted firms (especially firms that went bankrupt as a result of the closure of the cod fishery). Unfortunately, the estimates from the authors are circumspect. For example, it is very difficult to disentangle growth due to ACOA and growth due to economic conditions and other exogenous factors. Furthermore, it may be that there is strong selection bias for applicants: only the most innovative and successful firms apply for and receive funding. Non-applicant or rejected firms may simply be poor performers. So comparisons to this group will always biased in favour of the program. Other detrimental critiques can be made of the analysis, most of which can be found in Watson (2000).

The Office of the Auditor General of Canada recently conducted an audit of ACOA to "…assess how well the Agency's programs reflect its mandate, objectives, and priorities…We looked for compliance with key authorities, such as the Financial Administration Act, the Canadian Environmental Assessment Act, and Treasury Board policies and guidelines." (OAG, 2001). The Auditor General found that nine out of 28 non-commercial projects were incapable of sustaining themselves. The auditor recommended that ACOA adopt a policy to place limitations on funding for not-for-profit institutions. Expected results of federal-provincial agreements were often unclear. For example, ACOA has agreements with CBDCs and regional economic development organizations; of the eight agreements the expected outcomes in only three were "clear" and "concrete". The auditor also found that ACOAs administrative and policy role was not clear with CBDCs and regional economic development organizations. In addition, the auditor complained that performance evaluations of

[12] Audit and Evaluation Branch of Industry Canada contracted Ernst & Young LLP to conduct the audit, which began in the fall of 2002 (Industry Canada, 2003).

Table A2
Canadian program evaluation

Author(s)	Program under investigation	Method	Results
Performance management network (2003)	Technology partnerships Canada	• review of program files • review of electronic databases on TPC and IRAP-TPC • interviews with management and staff • telephone survey of 99 out of 133 TPC clients • telephone survey of 120 out of 323 IRAP-TPC clients • six case studies (four for TPC and two for IRAP-TPC)	• mixed results which are somewhat vague • success was measured via incrementality through the use of surveys of program participants • the results of the survey found that 85% of TPC and 89% of IRAP-TPC projects had full or "high" incrementality
Audit and Evaluation Branch, Industry Canada	Technology Partnerships Canada	• 20 interviews at TPC and IRAP-TPC • sample of 58 TPC contribution files • sample of 25 IRAP-TPC files	• management practices→good with minor recommendations for improvement • rules and regulations for transactions→full compliance was observed • rules and regulations for clients→full compliance was observed • recommended a 3rd party audit of clients who claim that they could not repay TPC
Usher (1983)	IRAP	• neoclassical economics and the notion of "incrementalism" • compares IRAP to R&D tax credits	• IRAP being firm-specific is more costly to administer (bureaucratic costs plus dead weight losses to society) than a framework policy (such as tax credits) • thus a firm-specific policy such as IRAP has no advantage over a framework policy
Tarofsky (1984)	IRAP	• neoclassical economics and the notion of "incrementalism"	• IRAP does not collect enough data to enable a test of incrementality • IRAP is perhaps not the best vehicle for to promote uncertain research in the private sector—government research labs would be better • basic research under IRAP should be rejected
Task Force on Federal Policies and Programs for Technology Development (1984)	IRAP	• interviews	• program was a success
Ministerial Task Force on Program Review (1985)	IRAP	• summarizes other program evaluations	• program was a success
Report of the Standing Committee on Industry, Science and Technology, Regional and Northern Development (1991)	IRAP	• summarizes other program evaluations	• program was a success
National Advisory Board on Science and Technology (1992, 1994)	IRAP	• interviews • tested to see if IRAP met four criteria for the basis of science and technology research	• advised government to follow IRAP's integrated structure • IRAP diffuses science and technology knowledge to the rest of the economy
National Research Council (1990)	IRAP-C (Field Advisory Service)	• user interviews	• 86% of firms had increased their technical ability within four years • 90% of firms said that IRAP was very important to increasing their technical ability
Lipsey and Carlaw (1998)	IRAP	• tested to see the number out of 19 "criteria of success" that were followed	• claim that other studies have used a narrow definition of "incrementalism" prescribed by neoclassical economics • claim that their method is superior since it is broader: it includes knowledge externalities, the belief that there is no "optimal" level of R&D, that policy makers must use subjective judgement in terms of decision-making in such an uncertain area • IRAP met 16 out of the 19 success criteria
NRC (2002)	IRAP	• data and document review of the program • interviews with 120	• 12,364 IRAP funded projects culminated in 39,186 new/significantly improved products/ processes/services, this translates into 3.2

Table A2 (*continued*)

Author(s)	Program under investigation	Method	Results
		IRAP stakeholders • survey of 684 clients who obtained IRAP funding within a 1996–2001 timeframe • 26 projects evaluated using a socio-economic framework • program was compared to six international programs • "innovation impact" analysis was conducted using an innovation survey	innovations per funded project • $4.2 billion in sales are attributable to IRAP this translates into 11 times IRAP's total project budget • existing innovations due to IRAP are expected to bring $14 billion in future sales • the number of jobs directly attributable to IRAP is 12,025 • world-first innovations attributable to IRAP = 37% • Canada-first innovations attributable to IRAP = 66% • the present and future value to the federal government in terms of tax revenue was estimated to be 11 times that of the original IRAP program expenditure
Thomas and Landry (2000)	ACOA	• economic evaluation of the program	• ACOA's impact grew from $1.4 billion in 1992 to $3.7 billion in 1997 • for every dollar of ACOA expenditure there was a five dollar increase in GDP • ACOA reduced unemployment in Atlantic Canada by 2.8% • the incrementality of the program was estimated to be 67%
OAG (2001)	ACOA	• sample of 40 commercial projects and 68 non-commercial projects • measurement and reporting of ACOA's performance was also audited	• of 28 non-commercial projects nine were not self-sustaining • ACOA does not have a policy that places limitations on funding for not-for-profit institutions • the expected results of federal-provincial agreements between ACOA and CBDCs, ACOA and regional economic development organizations were "clear" and "concrete" in only three of eight instances • performance evaluations of federal-provincial agreements are rare • ACOAs role was not clear with CBDCs and regional economic development organizations • ACOAs performance reports seem to be based on solid evidence
OAG (2002)	Canadian Space Agency	• an organizational audit to determine how well CSA functions and how well it fulfills its mandate	• found many areas for organizational improvement • in-depth analyses of individual projects were not carried out
CSA (2002)	Canadian Space Agency	• internal performance evaluation • economic evaluation of	• economic benefits→satellites currently in operation; Canadarm2 (deployed on the International Space Station); participation in

federal-provincial agreements are rare. Finally, ACOAs internal performance reports seemed to be based on solid evidence and were deemed acceptable by the auditor.

Canadian Space Agency: The Office of the Auditor General of Canada recently conducted an audit of CSA to "…assess whether the Agency is implementing the Canadian Space Program with due regard to economy, efficiency, and effectiveness…how the Agency selects programs…how it monitors and evaluates those it funds…how the Agency ensures that it has the staff it needs… ∢ how it reports on its performance" (OAG, 2002, p. 5). The audit found many areas for improvement, however, they were primarily organizational. In-depth analyses of individual projects were not carried out.

The agency conducted its own evaluation in 2002 (CSA, 2002). Economic benefits were determined to be embodied by satellites currently in operation, by Canadarm2 (deployed on the International Space Station), and by participation in ENVISAT (European earth observation satellite). Concrete estimates for real economic benefits were not provided.

Defence Research and Development Canada: Defence Research and Development has experienced a 50.6 percent (nominal) increase in program expenditures from 1996 to 2005 (Table A1). As reported in DND (2001) "There has been a strong impetus for change over the last decade in the management, organization and strucuture of R&D organizations in general and government-sponsored R&D capabilities in particular…DRDC has undergone significant and fundamental changes…". For this reason, DND conduced an in-depth evaluation of Defence R&D Canada. The purpose of the audit was to benchmark DRDC with other S&T organizations (Australia, New Zealand, United Kingdom and Denmark), assess internal management and support systems, assess human resource management affecting R&D, assess the transition from a branch within DND to a Special Operating Agency. The key findings of the report were:

- DRDC has been faced with fundamental changes not encountered by the comparison group.

- Client satisfaction overall is high.
- R&D programs do not collaborate well with one another.
- There are too many R&D committees, client involvement is viewed as excessive.
- In terms of human resources—researchers are aging, faced with low staff morale and a lack of training.
- The transition to agency status was viewed positively.

A.2. Summary

Table A2 summarizes evaluations and audits of the five government programs under investigation in this study. To date it is apparent that IRAP has been audited/evaluated far more frequently than any other program.

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