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# GOVERNMENT ROLE IN R&D AND RESULT INDICATORS FROM SELECTED FEDERAL DEPARTMENTS[*]

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## Section 1 Background

The broad extent of benefits from research and development (R&D) activities is not easily measurable. Three reasons are often mentioned (KPMG, 2004, Bozeman, 2000, Salter and Martin 2001) to explain the difficulty in linking outcomes and impacts to research activities: 1) the indirect nature of research impacts; 2) the incrementality of research results from the world-wide knowledge base; and 3) the timeframe to assess the impact. Godin-Dore (2005) gave a nice illustration of the first issue, with the use of scientific publications to modify or create a new policy that would help change the behaviour of a particular group. While the scientific publication is the direct result of the scientific activities, the impact of such activity will be felt through a policy (indirect effect). Moreover, it is difficult to isolate the impact of a particular research from other research results (incrementality of research) or other external factors (such as education) to assess the final outcome. Finally, it may take several years before the real value of the research result be revealed or applied.

In the case of government R&D activities, a fourth reason also applies: the array of missions pursued by governments in several dimensions (social, economic, cultural, environmental, etc). While the business sector focuses on commercially viable technological solutions, government, through its R&D performing departments and R&D facilitators (e.g. Granting Councils), cover a larger array of dimensions (KPMG, 2004).

A literature review (e.g. Salter and Martin, 2001, Wolfe 1997, KPMG 2004) on the roles and benefits for government to be involved in R&D activities are summarized by: 1) performing and funding R&D to contribute to the generation of knowledge; 2) training of highly skilled workers and researchers to allows firms to stay competitive, and public labs and universities to fulfill their mandate; 3) facilitating the transfer of knowledge and commercialization to ensure that the knowledge generated spills-over to the entire economy.[1] Given that usually departments or agencies fulfill more than just one role, the linkages of input to output and outcomes for a given department are highly complicated.

In Canada, the accounting of federal R&D activities performed and funded by all departments is aggregated annually to get an overview of national R&D activities. Efforts have been made recently to also cover commercialization indicators by departments. In that regard, Canada leads the way in collecting Intellectual Property revenues in universities and federal departments using national surveys. However, commercialization is only a partial measure of the impact of scientific activities.

[1] In a highly cited paper, Salter and Martin (2001) attribute 5 benefits for publicly funded basic research: 1- increasing the stock of new useful knowledge, 2-development of new instrumentations and methodologies, 3- development of highly skilled workers, 4- development of national and international networks, and 5- development of skills to solve complex issue. These benefits were first described by Wolfe and Salter (1997) for the Canadian context. KPMG (2004) attributes the following roles for government S&T (excluding higher education): R&D performance for generating knowledge; S&T in support of programs and regulatory frameworks; and R&D support and facilitation in providing advice and financial support for third parties to perform R&D.

A new government-wide initiative on the collection, management and reporting of departmental activities provides a new way to measure information on the results and benefits of S&T activities. Federal departments must now provide indicators of the expected and realized benefits of all their activities.[2] To date, however, no systematic exercise has been performed to compile efforts made by departments to monitor the expected and realized benefits of departmental scientific activities.

This paper seeks to address this gap and provide new insights on the efforts of departments and agencies to monitor their research and development (R&D) investments. Indicators from major departments and agencies have been collected and compiled using the information already available through administrative documents. To make sense of all the information collected, results indicators are aggregated in accordance to the different roles the federal government plays in the national innovation system.

This paper is divided into four sections, each examining different elements of R&D indicators in Canada. Section 2 begins by presenting indicators available through official statistics and complementary information from federal departments' administrative documents. Section 3 analyzes the available results indicators in light of a framework based on government roles by sector of performance, while Section 4 concludes the paper with a discussion on best practices and next steps to improving the reporting of R&D results indicators.

## Section 2 –Official R&D data and new reporting of government activities and results

### R&D expenditures by department and sector of performance

Statistics Canada collects and publishes official data on R&D performed and funded by the federal government (see Statistics Canada, Catalogue No. 88-204). This is done primarily through the annual survey on federal scientific activities in which Statistics Canada asks departments and agencies to detail their scientific activities by several variables: performing sector; type of activities; major fields of science; and the socio-economic objective of the activities.

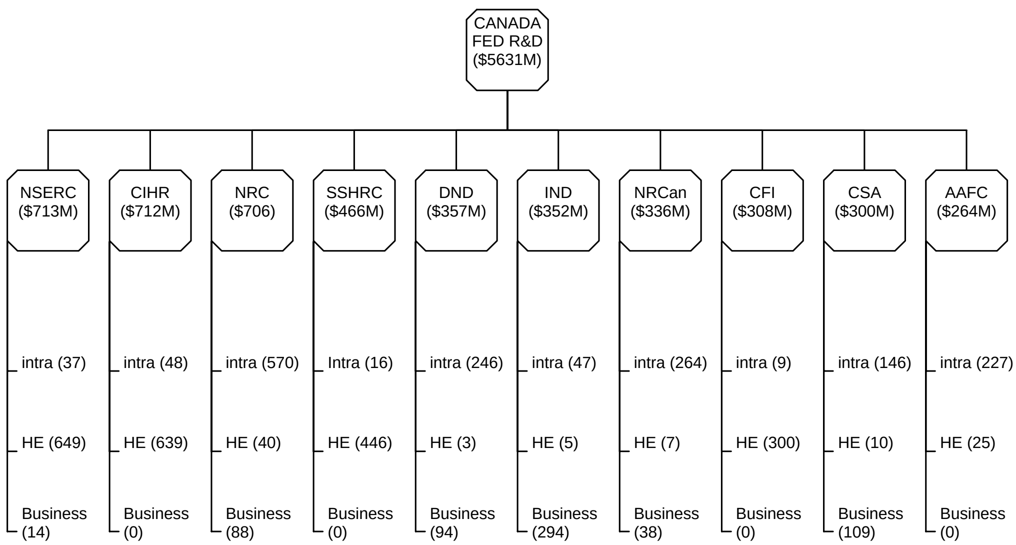
For the fiscal year 2004-05, the Government of Canada spent $5.6 billion on R&D activities, of which the top ten departments perform or fund more than 80 percent of all federal R&D activities (Figure 1). Of these ten departments, three are Granting Councils – Natural Sciences and Engineering Research Council (NSERC), Social Sciences and Humanities Research Council (SSHRC), and the Canadian Institutes of Health Research (CIHR) –providing funds to the higher education sector to perform research activities. Industry Canada (IC) is also an R&D facilitator as it provides funding to the business

[2] This is a Treasury Board initiative called Management Resources and Results Structure (MRSS). This initiative will be discussed in details in the next section, but suffice to say for now that it is government-wide initiative and all expenditures –not necessarily R&D expenditures – must be reported and monitored by program activities.

sector to perform R&D.[3] Other departments, such as the National Research Council (NRC), Natural Resources Canada (NRCan), Department of Defence (DND), and Agriculture and Agri-Food Canada (AAFC) mostly perform intramural R&D to fulfil their missions. The Canadian Space Agency (CSA), perform intramural R&D as well as provides funding to the business sector (in almost equal part) to fulfil its mission. Finally, the Canadian Foundation for Innovation (CFI) provides research infrastructure (equipment, building, sophisticated database) funding for the higher education.

The three Granting Councils (NSERC, CIHR, SSHRC) along with the CFI account for 93% of all higher education R&D activities funded by the federal government. NRC is by far the more important R&D performer (intramural) with $570M, accounting for about one quarter of all R&D performed within the federal government. Finally, Industry Canada (with the Technology Partnership Canada program) is the largest funder of business R&D, followed by the CSA and DND. These three departments account for more than two thirds of all business R&D funded by the federal government.

**Figure 2: R&D Federal system --Top 10 R&D departments and Agencies, 2004-05**




Note: RD=Research and Development; intra=intramural R&D, HE=Higher Education sector, Bus=Business sector, RSA=related Scientific Activities. Source: Statistics Canada, special tabulations, 2006

The concentration of R&D activities within a few departments makes it possible to focus our attention, for the purpose of this paper, on the major departments with R&D

[3] The mandate of facilitator organizations (IC, the three Granting Councils) is to facilitate the conduct of R&D or technological innovation by third parties, usually through the provision of financial support (KPMG, 2004). Contrary to R&D performing departments, these organizations usually do not perform R&D but manage R&D grants and contracts. In Canada, federal government finances up to $5.6B in R&D activities, and around 40% of this amount is performed internally (intramural R&D). The remaining is contracted-out to the higher education, Canadian business sectors, and other Canadian or foreign performers. (Statistics Canada, Service Bulletin, Vol 29, no 7, 2005)

activities. The three granting councils, NRC, NRCan, National Defence, Industry Canada, Canadian Space Agency (CSA) and Agriculture and Agri-Food Canada (AAFC) are all analyzed[4]. Note that intramural R&D activities are dispersed around several departments, but unfortunately these expenditures are very difficult to assess because R&D activities are often incorporated into larger programs that are not exclusively R&D-related.

Socio-economic objectives

The classification of S&T activities by socio-economic objectives provides useful information related to the intent of the investment. This classification allows departments to break down their R&D activities according to the purpose for which the expenditure is intended (OECD, Frascati Manual, 2002). Categories include, among others: public heath; defence; infrastructure; pollution, protection and conservation of the environment, industrial production and technology, and non-oriented research. The three largest categories of Federal R&D are: public health (22% of all federal R&D), industrial production and technology (18%), and non-oriented research (11%) (see Table 1).

**Table 1 Federal R&D expenditure by socio-economic objective, 2003-04**

| **Socio-economic objective** | **($M)** | **(% of total)** |
|---|---|---|
| Public Health | $1,155 | 22% |
| Industrial Production and Technology | $967 | 18% |
| Non-oriented research | $582 | 11% |
| Energy | $455 | 8% |
| Agriculture | $361 | 7% |
| Environment | $349 | 7% |
| Space | $318 | 6% |
| Defence | $273 | 5% |
| Social structure and relationship | $230 | 4% |
| Infrastructure | $207 | 4% |
| Others | $458 | 9% |
| Total for all socio-economic objectives* | $5,355 | 100% |

* indirect cost are excluded

The socio-economic objectives of R&D investments are also available by department. Of all departments funding or performing R&D, around 60% classify all their R&D expenditures in one socio-economic category. For instance, four out of the ten larger R&D departments devote all their R&D activities in one category. They are: AAFC in agriculture, CIHR in public health, CSA in space, and DND in defence. While it is understandable that some departments would have only one socio-economic purpose, the range of programs run by departments shows that they also fulfill several roles.

Commercialization data

[4] CFI, in providing infrastructure funding for the higher education, will be mainly analyzed through the Granting Councils.

Most R&D data focus on the input side (expenditures and personnel), with two notable exceptions, commercialization and bibliometric variables. Regarding commercialization variables, data on patents (new applications, those issued and held), licences (new and active), royalties, invention disclosures, and spin-offs have been collected and published since 1998. As shown in Table 3, only few departments have acquired patents and licences, received royalties, and created spin-offs.

Comparison of departments is not easy as some focus more on research side (such as NRC, Environment Canada) while activities of other departments are more on the development and technical applications side (IC-CRC, DND-DRDC), and therefore, the latter are more likely to receive IP revenue. Therefore, dividing these measures by R&D expenditures would not give an accurate picture of the real productivity of these departments.

**Table 3- Commercialization Measures from Federal Departments, 2002-2003**

| Department | Patents held (n) | Active licences (n) | Royalties (,000$) | Spin-offs (n) |
|---|---|---|---|---|
| | | | | |
| AAFC* | 164 | 355 | $3,573 | 11 |
| IC-CRC | 225 | 298 | $1,409 | 7 |
| CSA | 30 | 58 | $49 | 0 |
| F&O | 18 | 13 | $580 | 0 |
| DND-DRDC | 222 | 80 | $1,065 | 0 |
| EC | 35 | 47 | $748 | 5 |
| HC | 10 | 12 | $55 | 1 |
| NRC | 603 | 304 | $7,300 | 64 |
| NRCan | 153 | 236 | $730 | 3 |
| | | | | |
| TOTAL | 1,460 | 1,403 | $15,809 | 95 |

*: Canadian Food Inspection Agency is included in AAFC total.
Source: Statistics Canada, Federal Science Expenditures and Personnel, IP Management Annex, various years

Public monies account for a large part of the financing of higher education R&D. In Canada for 2003, the Federal Government provide direct funding of more than $2B, and provincial government for around $1B. Adding this direct support of governments to the indirect funding through the General University Fund (estimated at more than $1.6B), around 60% of Higher Education R&D is financed by governments.[5] It is therefore not surprising that commercialization results from that sector are also of interest to governments.

[5] General University Fund (GUF) are the funds which higher education establishments allocate to R&D from the general grant they receive from the Ministry of Education or the corresponding provincial or local authorities in support of their overall research and teaching activities. (OECD, Science and Technology Scoreboard, 2001)

Detailed information on commercialization activities of universities and research hospital are available at the aggregate level (Table 4). These data are not disaggregated by universities, but can be obtained using other sources such as from the Association of Universities Technology Managers (AUTM)[6].

**Table 4 Commercialization measures of universities and research hospitals, 2003**

| Indicator | 2003 value |
|---|---|
| Invention disclosures | 1,133 |
| Inventions protected/patented | 527 |
| Inventions rejected | 256 |
| Patent applications | 1,252 |
| Patents issued | 347 |
| Patents held | 3,047 |
| New licenses and options | 422 |
| Total active licenses and options | 1,756 |
| Income from IP commercialisation ($thousand) | $55,525 |
| IP income distributed to inventors and co-inventors ($thousand) | $19,418 |
| IP income distributed to the institution or to administrative units within ($thousand) | $22,121 |
| Spin-off companies created to date | 876 |
| Start-ups that were provided space at the institution | 74 |

Source: Statistics Canada, 2006, 2004 Survey of Intellectual Property Commercialization in the Higher Education Sector Preliminary release No. 1 (January 27, 2006)

Bibliometric indicators

The second set of indicators widely used to assess research result is bibliometrics (publications, citations and impact factors). A publication in a referee journal is seen as a valuable output as it signals not only the work done by the researcher(s) (useful for administrative purposes), but it also gives an idea of the quality as only papers with value added for the field and uses sound methodology would be retained in referee journals.

**Table 5 Share of scientific publications for selected sectors in Canada, and World-wide, 1993, 1999, 2004**

| | 1993 | 1999 | 2004 |
|---|---|---|---|
| *Within Canada* | | | |
| Federal Government | 12.5% | 11.2% | 11.4% |
| University | 82.0% | 84.1% | 84.3% |
| Others | 5.5% | 4.7% | 4.3% |
| ***Canada total*** | ***100.0%*** | ***100.0%*** | ***100.0%*** |
| | | | |
| *World-wide* | | | |
| Federal Government | 0.6% | 0.5% | 0.5% |
| University | 4.1% | 3.8% | 3.8% |

[6] Note that information from the AUTM covers only selected universities and research hospital. For more information on the survey and the data, go to http://www.autm.net/surveys/

| | | | |
|---|---|---|---|
| ***Canada total*** | ***5.0%*** | ***4.5%*** | ***4.5%*** |

Source: Observatoire des Sciences et des Technologies, special tabulations, 2006.

While publications could, by itself, be used as a proxy for quality, better benchmarks to assess the quality of publications are citations and impact factors. Indeed, while a publication can be considered an output of research (direct result of the research), citation is considered an outcome because it is an indication that the publication is used by others to advance the knowledge-base of a particular scientific field. Some departments (e.g. NSERC and Environment Canada) have contracted recently consultant firms specializing in bibliometrics to assess the number of publications as well as their impact (citation and impact factor) of research financed by their department.

Publications and commercialization measures are certainly important indicators of results from R&D investments, but they do not cover all government activities. Government performs intramural R&D or facilitates R&D (by financing basic research through Granting Councils) for several purposes that cannot be captured by these indicators. For instance, the use of research findings in policies, guidelines, and regulations cannot be captured by bibliometrics (citations in public policies or regulations are not taken into account in usual bibliometrics) or by commercialization measures. Another aspect of government activities that cannot be captured by these indicators is to take an emerging field with no or few technological applications and develop that field to the extent where technical and commercial applications are now possible and allows commercial firms to tap into that knowledge.

Administrative data

The federal government plays several roles in R&D, but most available data are on the input side with few exceptions on the output side. Therefore, looking at administrative data (e.g. departmental reports, direct interviews with program managers, program evaluations, etc) might be a good complementary source to collecting information on roles other than the commercialization role of the government in R&D activities and on the longer-term impact of these investments.

A promising approach is to use the new accounting structure developed by the federal government since 2004-2005. This new system, Management Resources and Results Structure (MRRS), is an "integrated modern expenditure system and represents a new approach to the collection, management and reporting of financial and non-financial information" (Industry Canada 2005).[7] A key component of the MRRS is the Program Activities Architecture (PAA). The PAA links all departmental activities (by level: sub-sub-program activities, sub-program activities) to departmental strategic outcomes. More importantly for this paper, this system tries to link each activity with their expected results and results indicators.[8]

[7] For more details on the MRRS, go to the Treasury Board of Canada Secretariat website http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/mrrsp-psgrr/siglist_e.asp

[8] Two caveats regarding the MRRS must be identified: first, all activities must be reported—not only R&D. This might be a problem for departments involved in other than R&D activities such as Industry Canada, NRCan, Environment Canada, where it is difficult to identify and isolate R&D activities from the other

NSERC is a good example of what we can get from this new way of reporting departmental activities and results (see Box 1). Almost the whole NSERC budget is devoted to science and technology (S&T) activities (S&T planned expenditures of $814M over a total planned budget of $850M for 2004-05), which makes it easier to extract relevant information from their reports than other departments that are not entirely dedicated to S&T. The PAA is structured in a way to link each activity (from sub-sub-program activities to sub-program activities to program activities) to a general goal stated as a strategic outcome.[9] For each activity, financial information is provided and it is therefore possible to gather the place and importance of each of the activities. (See annex B for the overall NSERC structure as well as the structure of the other departments.)

Input, output, and outcomes measures linked to R&D programs can be extracted from the MRRS. While some indicators are needed to assure that public monies is well administrated and well spent, other indicators assess what is achieved with that money. Results from research can take several forms, from outputs (direct results of the research –e.g. publications, patents, training of HPQ) to outcomes (consequences of the outputs –e.g. policies or regulations that originate from publications) and impacts (change in behaviour –e.g. higher ethics, decrease of chronic illness in population).

**Box 1: NSERC Program Activity Architecture with selected results indicators (2005-06)**

| Activities | ($M) | Selected results indicators |
|---|---|---|
| **S.O Highly skilled Science and Engineering professional in Canada** | | |
| ***1.0 People*** | **280** | |
| 1.1 Promoting S&E | 4 | |
| 1.2 Supporting Students and Fellows | 124 | |
| *1.2.1 Undergraduate Student Res.* | *19* | # students gaining research experience/job training; average salary of recipients/ completion rate vs. general population |
| *1.2.2 NSERC Postgraduate School.* | *58* | same as 1.2.1 + # of masters and Ph.D motivated to pursue further research/training |
| *1.2.3 Canada Graduate Scholarship)* | *25* | same as 1.2.1 |
| *1.2.4 Postdoctoral Fellowship* | *23* | same as 1.2.1 (for postdoctoral fellows) + # continuing on academic path |
| *1.2.5 Industrial Research Fellowship* | | # Ph.D gaining research experience in industrial setting |
| 1.3 Attracting And Retaining Faculty | 144 | |

non-R&D activities. Second, the system is new, and some departments are struggling to identify and report result indicators. Refinement in the reporting of result indicators is expected in the next years, as departments will gain experience.

[9] Based on their 2005-06 PRR, strategic outcomes of NSERC would be reached through three program activities (Tomorrow Innovators (**People)**; Brain Gain (**Discovery)**;and Realizing the Benefits (**Innovate**)), and for each of them, a myriad of sub-program and sub-sub program activities.

| Activities | ($M) | Selected results indicators |
|---|---|---|
| *1.3.1 Canada Research Chairs* | *113* | % of Chairs awarded to academics working in Cdn universities vs. foreign attracted; importance of the chair to accept/keep position in Canada and quality of research; # of research centres created or expanded with Chair; relative research productivity vs. other researchers, # of students and postdoc trained |
| *1.3.2 Industrial and Other Res. Chairs* | *28* | average financial funds and in-kind leveraged from partners; # of publications and presentations; # of patents, IP incomes, innovations; # trained in area relevant for industrial sector, # of collaboration (active and new) with industry partners |
| *1.3.3 Prizes* | *2* | qualitative assessment of impact of award on awardees, change in research funding for awardees vs. other grantees, perception of awardees from community |
| **S.O High quality Canadian-based competitive research in Natural Science and Engineering** | | |
| ***2.0 Discovery*** | **432** | |
| 2.1 Funding Basic Research | 387 | |
| 2.*1.1 Discovery Grants* | *330* | # publications and impact factor of publications; # of patents, licences, copyright, innovations; # of policies influenced or created, # trained gaining research experience |
| … | | |
| 2.2 Funding Research in Strategic Areas | 56 | |
| 2.2.1 Strategic Project Grants | *51* | same as 2.1.1 + 1.3.2 |
| … | | |
| **S.O Productive use of new knowledge in Natural Science and Engineering** | | |
| ***3.0 Innovation*** | **117** | |
| … | | |

Note: Only the Program activity "People" is extensively developed in this box, the other program activities are shown only for illustrative purposes. Source: NSERC DPR 2004-05, RPP 2005-06, and private conversation with NSERC officials.

## Section 3 Matrix of result indicators by S&T roles and sector of performance

This section looks at the result indicators used by federal departments and agencies to monitor their R&D investments. The information on results indicators mainly comes from administrative documents. Officers from R&D departments were asked to provide their list of result indicators, and most of them provided the section of their Management Resources and Results Structure (MRRS) with the program activities and their related results indicators.[10] Financial information and the actual numbers related to the indicators were not provided. (See Annex B for list of indicators by departments and programs)

[10] Some departments also gave complementary documents describing their methodology to track down results, usually helped by a logic model. Note also that additional information from some departments is still arriving and therefore, matrix A and its related analysis might still change.

Indicators compiled are then aggregated along three different government R&D roles and by sectors of performance. The three major government roles are knowledge creation; training of HQP and researchers; and knowledge-transfer and commercialization. Increasing the pool of useful knowledge is a major roles historically devoted to governments. Government can either perform R&D internally or fund other organization to perform R&D in order to generate knowledge that will be used in the entire economy. Training of highly qualified personnel and more specifically researchers is another well-established role of government, and is usually fulfilled through the higher education system. Finally, assuring the transfer of knowledge (and technology) and facilitating the commercialization of such knowledge is seen nowadays as another major role (government as a bridging agent) for any government. Note that knowledge-transfer can be one way e.g. government institutions providing technical and strategic advice for technology diffusion or policy making, or two ways–e.g. collaboration and alliances between different institutions. [11]

Indicators are also aggregated by three major sectors of performance. Some programs are designed for funding researchers in university, some for performing research within departments, while others are business-related support for technology development. As a result, indicators to assess the output and outcomes will vary according to the specificity of these programs (Bordt, Hamdani, Therrien 2006). The higher education and not-for-profit sectors constitute the first category, while the federal sector (intramural activities) and the business sector constitute respectively the second and third categories.

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[11] This is a shortened version of the initial paper. In the longer version, an entire section is devoted on the different roles of government in R&D activities, and R&D programs are aggregated along the three roles and sectors of performance to illustrate the range of missions departments must fulfill. To get the longer version, please contact the author at therrien.pierre@ic.gc.ca.

Matrix A. Major Result Indicators by Role of Government and Sector of Performance for Selected Federal Departments and Agencies

<table>
<tr><th></th><th>Knowledge creation</th><th>HQP</th><th>Knowledge Transfer & Commercialization</th></tr>
<tr><td>Sector of performance</td><td></td><td></td><td></td></tr>
<tr><td>Higher Education and Non for Profit Organization</td><td rowspan="2">OUTPUT<br>- Scientific publications (by scientific field)<br>- Patent (by technological field)<br>- Diversification of scientific fields of S&T covered by federal R&D funding<br>- Technology advancement (safer, greener technology)<br>- Improved measurement methodology and tools (for risk management, etc)<br><br>OUTCOME/IMPACT<br>- Citation, Impact factor<br>- Patents<br>- IP income<br>- Spin-offs and spin-ins<br>- Change of behavior for target population<br>- Peer-review of knowledge generated<br>- Policies, guidelines, programs, regulations created/modified<br>- Leverage impact (financial and in-kind) of departmental investment (share of partners contribution vs. department)<br>- Perception of non-academic about relevance of knowledge generated</td><td>OUTPUT<br>- Graduates and Fellow gaining research experience and job training<br>- Graduate (Ph.D and M.D.) by field<br>- Graduates and Fellows trained in area relevant for industrial sector<br><br>OUTCOME/IMPACT<br>- HQP transfer by industrial sector<br>- Employment and wage of former students<br>- Productivity of awardees academics compared to non-awardees.</td><td rowspan="2">OUTPUT<br>- Nb. and value of collaborations (intra, inter-sectoral and international)<br>- Formation of Networks (national and international)<br>- Publications for non-scientific users<br>- Nb. of visit to website<br>- Media coverage from outreach activities<br><br>OUTCOME/IMPACT<br>- IP income<br>- Patents<br>- New firms<br>- Training of graduates and Fellows<br>- Policies, guidelines, programs, research agenda, regulations created/modified<br>- Fee for services<br>- Awareness and change of behaviour for target population<br>- Nb of external requests for publications</td></tr>
<tr><td>R&D performing Federal Departments and Agencies</td><td>OUTPUT<br>- Training expenditures per S&T staff<br>- Graduate student supervised<br>- HQP involved in programs<br><br>OUTCOME/IMPACT<br>- Scientific presentations<br>- Conference attended<br>- Positions held on Int'l Editor Boards<br>- Internal/external awards<br>- Positions held as adjunct professorship<br>- HQP transfer by industrial sector</td></tr>
<tr><td>Private Firms</td><td>OUTCOME/IMPACT<br>- New firms/ new jobs<br>- Leverage of private R&D<br>- Technologies brought to higher readiness level to advance technological capacity<br>- Nb (and value) of technologies developed; and used by industry<br>- Leverage of private R&D<br>- New products/processes<br>- Return of Investment (ROI)<br>- Repayment of conditional grants</td><td>OUTCOME<br>- Nb of graduate students trained in a given industry<br>- Nb of experts by industry developed through the programs</td><td>OUTPUT<br>- Advancement of emerging technology<br>- Technological-related advices for clients<br><br>OUTCOME/IMPACT<br>- Access to new technologies<br>- Economic performance (and survival rate) of client vs. non-client<br>- New-technology-related firms<br>- Nb of firms using technology supported by programs.</td></tr>
</table>

Knowledge-creation

Sets of indicators for the category *knowledge-creation* are very different depending on whether the program is intended for the public or the private sector. Results indicators for business support programs in this category are focused on economic and technological effects of the research on firms, and on the Canadian economy. This is in line with the usual innovation models (the old linear innovation model or even with the chain-linked model) where firms play a more important role in developing and adapting technologies than in basic research. Key results indicators for such business-related R&D programs are the number of technologies brought to a higher readiness level (more mature technology, set standard, etc), number (and value) of technology developed by these programs and used in industry, and leverage of private R&D to develop the technology further. The number of new products and processes, as well as the number of new firms and new jobs created through the programs (incubator type of programs) are other key sets of indicators of business-related programs. Finally, because these programs are usually more on the technology development or applied research side (than basic research side), methods used in the private sector (such as return on investment) for such projects could also be used, but with caution.[12]

Programs intended for knowledge-generation in the public sector are generally those where the problem of attribution, "incrementality" of research, and timeframe to assess results are the most acute. To somewhat "get around" the problem, it might be best to use short-term measures such as citations as a proxy for the usefulness of research funded (by field of study and department or by programs). Longer-term measures (outcomes and impacts) include indicators that measure the variation (change) in the target population's behaviour. As already mentioned, attribution of any behaviour change for a given target population (e.g. lower mortality rate for the Canadian population) cannot be easily linked to a given research project or even with one particular field of research (and more so if it is a broad goal such as Canadian health). However, it might be possible – to a certain extent – to draw such indirect linkages if the target population is well defined (new drug increasing life expectancy for patients with a given illness; the greater use of efficient energy sources from development of novel, environmentally sustainable technology). Case studies and peer-reviews can also be used to give a qualitative view of the usefulness and relevance of the research funded and their findings. A particular kind of case study – historical trace study – traces back the influence or contribution of a particular program or technology for firm creation or new technologies. IC-CRC has performed such a study tracing back the influence of the agency in the creation of firms (see Annex B).

[12] Caution is required if we use the same tools for comparing the outcome of public from privately funded R&D projects. As stated in the last section, the 1996 Federal S&T Strategy explicitly stated that government R&D expenditures should focus on fields where the private sector does not operate (either due to low technology opportunity, lack of appropriability of results from their research, etc). Therefore, indicators developed for the private sector (e.g Return on investment (ROI)) are not necessarily suitable for the public sector or ROI from public sector activities cannot be directly compared to ROI from the private sector.

Depending on the field of research, the number of patents (and quality of patents as defined by the triadic families), spin-offs, spin-ins, and new technology applications derived by the basic research as well as policy or regulations created or modified are other important outcomes from knowledge-creation programs.[13]

Training of HQP and researchers

The second category of programs deals with the main objectives: to develop and nurture a pool of excellent researchers in Canadian universities and research centres, and to more generally assure that a highly skilled workforce spills over into the Canadian economy. The granting councils have several programs devoted to the training of the new cohort of researchers and HQP as well as to attract or retain already well-established researchers in Canadian universities. Result indicators used are the number of graduate students and doctorate fellows trained, or those with a specific training (for industrial purpose or for research). Outcome measures used to assess HQP training are the distribution of such trainees in industrial sectors (other than in the education sector); or the employment rate (or wage) of those who received a grant versus other graduates. Indicators regarding HQP spreading-out into the economy would be a proxy for industrial sector innovation capability, as these workers would bring disembodied knowledge from within their firms; would create links with the research base by staying in contact with their alma-mater; and would increase the capacity of firms to resolve complex issues (Salter and Martin, 2000). A comparison of productivity (research output such as publications, citations, impact factors, and patents) between researchers who received research chairs with those who did not may be used to measure the outcome of retaining/attracting these researchers in Canada.

There is usually no specific program associated with HQP in R&D performing departments (or at least the cost associated to the training and monitoring of the new cohort of researchers in public labs are not listed). However, training budgets are available for researchers working in public labs and other departments. Departments measure the results of such investment in their workforce by the average expenditure of training by S&T workers, the number of staff presentations at scientific conferences, the conferences attended, and the number of internal and external awards received by their S&T workers. Note that when relevant, some departments also use the number of supervised graduate students hosted by the department/institute as a result indicator for HQP. Finally, departments also take into account S&T workers trained in federal labs who left for universities, the private sector, or another federal department (transfer of HQP in industrial sector); and the number of S&T staff also working part-time in universities or colleges (adjunct professorships).

[13] Few indicators are included in more than one category in Matrix A in order to avoid duplication. However, it must be noted that in department lists (as seen in Annex B), several indicators are included in programs with different roles, which show that each program fulfills more than just one S&T role. For instance, most programs from the granting councils have a particular clause asking for the training of students and fellows.

As for R&D performing departments, there is no specific item for HQP training in business-support R&D programs. However, some programs use as indicators, the number of university graduates that gain experience in a specific industry, and the number of experts by industry developed through the business-related program.

Knowledge-transfer and commercialization

The third category of programs deals with knowledge transfer and commercialization. Knowledge-transfer can come from collaborations, and research networks. Programs aimed at forging alliances and collaborations use mostly the number of collaboration projects, and the creation of research networks as their first and more direct output.

The main goal of programs facilitating collaborations (with researchers in the same scientific field, in different scientific fields of expertise, between academics and local community workers) is to develop a new kind of knowledge that would resolve or at least, allow a better understanding of complex issues. Therefore, these programs are very knowledge-creation oriented and use the same results indicators (patents, publications, citations, graduates trained, new products and processes, spin-offs) as seen before. However there is a need for new indicators that would show the value-added of collaborations (and the use of networks) to solve complex issues that would not have been solved by individual researchers. Note that SSHRC has made a first step to measure this by providing examples of value-added to research by networking, collaborating, and multi-disciplinary research as indicated in their list of result indicators.

In the same manner, some programs are aimed at knowledge-transfer between academics and local community workers. Other than usual bibliometrics variables are needed to measure the extent to which these programs work because scientific publications might not be the preferred path to disseminate the knowledge-created. The indicators used for these specific collaborations are qualitative assessments trying to measure the relevance of knowledge-transfer and the use of research results (or more generally as a change of behaviour by community and university actors).

Finally, in the case of the private sector collaborating with federal departments (such as DND-industrial research program), results indicators used are the advancement of emerging technology and their subsequent use by industry.

Knowledge-transfer can also come from programs aimed at disseminating research results to the public (to increase the public's awareness of S&T issues) or to policy makers (to create or modify policies and regulations). Indicators for the dissemination of research results to the public includes the number of persons from the targeted audiences reached (through outreach activities), media coverage, web visits to web sites, and non-scientific publications. Surveys or media coverage could also be used to assess a change in the public's science awareness. Results indicators regarding dissemination to policy-makers include: the number of programs, policies, and regulations created or modified, as well as changes in research questions and political agendas.

Commercialization is another form of knowledge-transfer (even if only a small share of public funding of R&D is intended to be commercialized). The Granting Councils and R&D performing departments are becoming more and more involved in commercialization, and new programs have been implemented to deal with this issue. Indicators such as Intellectual Property income, royalties on licences, and patents are, of course, used by the Granting Councils as well as by R&D performing departments. Other indicators used by R&D performing departments include the number (and value) of fee-for-service clients (paying for expert advice, contract research and sales).

Knowledge-transfer in business-related support programs might take on the specific form of technology-transfer. Outcome measures would be the economic performance and survival rate of firms acquiring a particular technology (technology-based advice program such as NRC-IRAP), the number of new technology-related firms, the number of firms having access to a given technology, and measuring the innovation capacity of firms.

## Section 4. DISCUSSION ON BEST PRACTICES (PRELIMINARY)

In the second section of the paper, available S&T indicators in the public domain were compiled and analyzed. While detailed information on the funding of R&D and the sector of performance is widely available, we still have only scant information on the purpose of the funding. Using the OECD-Frascati Manual (2002), information on the socio-economic objectives is provided by department. This information is useful as we can compare our funding in a particular field of science with other countries or over time. With that information, it was possible to set trends and observe that, for instance, in Canada the share of funding in public health has increased significantly in the last 10 years, a trend in line with investments in most other OECD countries.

However, there is no classification of federal R&D expenditures by the different roles played by the government. For instance, there is no official data on how much the government spends on curiosity-driven knowledge generation, on research in "strategic" topics, for technology development, or for policy and regulation purposes. To fill this gap, the United Kingdom developed another indicator assessing key roles of government for public disbursement. This indicator, called "the primary purpose of research", has six categories, covering general support for research to advance the knowledge base, policy and technology support, training of graduate students, and technology transfer.[14]

[14] The six categories are: **1) general support for research:** all basic and applied R&D which advances knowledge for its own sake; support for postgraduate research studentships (PhDs); **2) Government services**: R&D relevant to any aspect of Government service provision (defence included in this category); **3) policy support**: R&D which Government funds to inform policy and for monitoring developments of significance for the welfare of the population; **4) technology support:** applied R&D that advances technology underpinning the UK economy (excluding defence). The category includes strategic as well as applied research, and pre-competitive research; **5) technology transfer**: activities that encourage the exploitation of knowledge in a different place to its origin; and, **6) taught course awards:** includes awards for Masters degrees (with a high degree of research methods training, leading on to PhD programs). Note

Building a comparable classification (comparable, not necessarily identical) in Canada would be a good complement to the socio-economic objectives classification already collected in Canada. Using the U.K. classification as a general framework and trying to develop more detailed categories would be better than directly replicating it. For instance, using the U.K. classification directly would not improve our understanding of the Department of National Defence, as all their R&D activities falls into government services (recall we had a similar problem with the socio-economic objectives classification where all DND R&D activity falls in the "Defence" category). These two classifications together would help policy-makers and analysts to better understand where and why we investment in R&D.[15] This would be even more important given the Canadian situation with a decentralized federal S&T system, which makes the general assessment of the federal R&D funding very difficult, particularly since even a list of R&D program does not exist.

Setting an annual list or database of R&D programs run by all departments would be another improvement to the actual situation. With the right framework, such a database would help to assess federal competencies and strengths, as well as to point out imbalances and gaps in government actions. Programs listed would have information on the financing, the mission or purpose of the funding, target population of the research program (if projects within the programs are homogeneous enough to allow such a distinction), and input, output and outcome indicators. Note that even without information on result indicators, a list of R&D programs would still be highly valuable.

The database would be a refinement from the MRRS initiative as it would focus exclusively on R&D programs. As said earlier, the actual reporting methods make it almost impossible to gather reliable information on R&D investment in departments not entirely devoted to S&T. Some initiatives are already under way within departments to build their own S&T database. For instance, SSHRC is building databases regarding the outcomes of fellowships awarded, and the short-term outcomes of research; while CHIR has already put in place a framework for common performance measurements. NRCan is also working on a framework to better assess the resources devoted to S&T. These initiatives have to be taken into account in building a federal R&D program database.

A framework representing government R&D roles and the sector of performance of R&D was used (Section 3) to compile and analyze result indicators developed by the major departments involved in R&D activities. From the analysis, four general observations resulted. First, at the departmental level, methods used (logic models, case studies, historical tree of technology developed and firms created) and indicators developed seemed to be in line with international standards. Canada is not behind other countries in working to better understand the linkages between public R&D investments and results. However, Canada and many other countries continue to wrestle with a series of

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finally that only the first four categories are included in the international definition of R&D. (see the UK Office of Science and Technology website for more details http://www.ost.gov.uk )

15 Note that the UK still uses the socio-economic objectives indicator in addition to the primary purpose one as they both convey important and complementary information.

fundamental analytical challenges in linking public R&D investment to result. (Currie, 2005)

Second, R&D programs aimed towards higher education tended to use similar result indicators as those intended for R&D performing departments. While it can be expected that similar types of research performed in different sectors would end-up with the same results (and therefore the same result indicators can be used), it can also be expected that different indicators would prevail in each sector due to their specialization. For instance, a program in a R&D performing sector might produce more policy advice, or leverage more private R&D investment, while programs in higher education might produce more publications or might have greater impact on behavioural changes. For now, it is impossible to know, and without this knowledge, it is harder to develop new, improved indicators or to better understand the link between one type of research program and its impacts.

Third, indicators for capturing results from collaboration need to be developed. The number of collaborations (intra, inter-sectoral or international) and formation of networks are certainly a good indication of the willingness of researchers to collaborate, but it says nothing about the results of such collaborations. In the literature (e.g. Kanninen, Lemola 2006), it is implied that the number of collaboration projects is a proxy for technology-transfer (more collaboration imply higher knowledge transfer), but with such a measure, we cannot distinguish from fruitful to time-consuming/frustrating collaboration projects. Impact of research is measured using the usual bibliometrics (joint-publications, citations, impact factor), but indicators on the value added of such collaboration should be elaborated. Multi-disciplinary networks and collaboration are built to allow the analysis of complex issues involving distinct fields of science. Indicators showing the value added of collaborative teams (over individual researchers) would be a valuable addition to any result indicators list. Finally, bibliometrics (and indicators such as network formation) cover impacts on the scientific community (e.g. citations show that the knowledge generated is used by other researchers) but indicators of impact on the non-scientific community are still needed. Indicators on target population behaviour change can be targeted to policy-makers (change in policy/programs) or to the general public (change in perception or habit of Canadian citizen). Such indicators (and more generally indicators on impact on non-scientific community or user) are already included in the federal departments list of result indicators but need to be refined.

The fourth observation deals with linkages between programs within a department, or more broadly between programs all over the federal (and provincial) government(s). Rarely is a program explicitly linked to another, and rarely are the results of one program taken into account in administrating others. There are some exceptions, such as Canada Research Chair-Infrastructure. CFI is closely linked to Canadian Research Chair program through a specific sub-program (CRC-Infrastructure). But again, having a database listing all programs launched by the federal government (even better if we add the provincial governments R&D programs) would help to gain a better overview of government R&D efforts, making it easier for policy-makers to address funding gaps.

The last, but not the least, advantage to building and annually updating such an R&D program database is that it might lead to a better estimation of government intramural expenditures on R&D (GOVERD). Extramural R&D is relatively easy to report as contracts are usually given to R&D performers (unless it is a in-kind collaboration) and summing-up these transactions to get the overall extramural R&D expenditures is very simple. For intramural R&D, there is no such money trail. Reporting at the program level would require that departments detail their R&D expenditures more than ever. Using a bottom-up approach (from expenditures in R&D program to get the departmental expenditures, then summing up for the entire government) would then lead to more accurate GOVERD statistics.

## Conclusion

From this paper, suggestions have been made to improve our understanding of the rationale of federal R&D activities, to better organize the available information, and finally to better measure the results from federal R&D activities.

First, it has been suggested that a new classification for the rationale of government funding (that would complement the actual one dealing with socio-economic objectives) be implemented. The U.K. classification on primary purpose was given as example to be used, and if possible, improved upon to better represent Canadian needs.

Second, useful available information at the program level (such as the funding, rationale, intended results, realized output and outcomes) are lost at the overall government level. Organizing this information through a database of R&D programs would be an important step to linking R&D programs with each other, and consider where they fit in the innovation system, as well as to help give indications of potential imbalances in government actions. The details regarding the implementation, the management, and more importantly the benefits versus the costs (in time and money) of such a database have yet to be discussed. Some departments have already started building such databases (for their respective departments) and it has to be seen if it would be possible to gain from their experience and develop a similar database on a larger scale (at the overall government level).

Third, result indicators collected by the departments seem to be in line with what is collected in other countries. However, the scarcity of good indicators means that the same indicators are used to assess different programs with different purposes. Again, having a database with all R&D programs and their related indicators would allow a better understanding of the importance and the ranking of each indicators depending on the purpose of each program. Such a database would enable answering questions such as whether or not collaboration projects end up with more citations; or whether or not mission-oriented R&D programs are more often used in policy and regulation creation.

Finally, while a better understanding of the three major issues facing R&D result (indirect effect of research, incrementality effect, timeframe to consider) is needed to link efficiently R&D activities to outcomes and general impact on society, minor but useful initiatives could also be undertaken in the short run. Initiatives such as a new classification of government rationale for investing in R&D would help to better assess where federal government invests in R&D, while a federal database on R&D programs would help researchers gain a better sense of the utility of the indicators used and the need to develop new ones.

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**Annex A ACRONYMS AND ABBREVIATIONS**

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|---|---|
| AAFC | Agriculture and Agri-Food Canada |
| AECL | Atomic Energy of Canada Limited |
| CIDA | Canadian International Development Agency |
| CFI | Canada Foundation for Innovation |
| CIHR | Canadian Institutes of Health Research |
| IC-CRC | Communications Research Centre Canada |
| CSA | Canadian Space Agency |
| DND | National Defence |
| DND-DRDC | DND-Defence Research and Development Canada |
| DPR | Departmental Performance Report |
| EC | Environment Canada |
| F&O | Fisheries and Oceans Canada |
| GC | Genome Canada |
| HC | Health Canada |
| HQP | Highly Skilled People |
| IC | Industry Canada |
| MRRS | Management Resources and Results Structure |
| NRC | National Research Council Canada |
| NRCan | Natural Resources Canada |
| NSERC | Natural Sciences and Engineering Research Council of Canada |
| OECD | Organisation for Economic Co-operation and Development |
| PAA | Program Activity Architecture |
| R&D | Research and Development |
| RPP | Report on Plans and Priorities |
| RSA | Related Scientific Activities |
| SC | Statistics Canada |
| SSHRC | Social Sciences and Humanities Research Council of Canada |
| S&T | Science and Technology |