

**Association of Universities
and Colleges of Canada**



**Association des universités
et collèges du Canada**

**Measuring Success in Relation to Federal Investments in
University Research:
An AUCC Discussion Paper**

November 17, 2006

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and Colleges of Canada**



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EXECUTIVE SUMMARY

Around the world in recent years, increasing government investments in university research have been accompanied by increasing expectations. Governments want to see the results of public investments and expect accountability, and they want to be able to assess their countries' relative performance. This has led to greater interest in the development of indicators in this area.

Rather than employing the traditional input/output/outcomes/impacts categories with all of their definitional and methodological challenges, this paper proposes looking at the results of public investments in university research in two broad categories:

- *“First order” results* (the impacts of the investments on the quality and competitiveness of the university research environment); and
- *“Second order” results* (the “products” of the university research environment, their transfer or translation to the wider community and the ultimate benefits they bring to the wider community).

The two categories are inter-connected, as a quality research environment is a pre-requisite for good second order research results; and a good record of second order results help to attract the right resources and create the right linkages to sustain and further enhance a quality environment.

It is important to resist the temptation to search for the “magic bullet” indicator that would allow measurement of progress for each incremental dollar of public investment. When used in isolation, quantitative indicators offer a narrow and fragmented view of the world. Good practice involves the “agile” use of multiple evaluation tools, including both quantitative indicators and qualitative information, to reach policy-relevant conclusions.

First Order Indicators

Indicators to assess first order results include both traditional input indicators and a number of other indicators that are specific to the university research environment. It would be possible to set targets over time on a number of these indicators as well as measure the progress made towards meeting those targets.

Funding – Competitive funding of the four pillars of the university research environment is essential to create an internationally competitive research environment. While not without problems, such measures as GERD to GDP and HERD to GDP still provide a useful basis for international comparisons.

Enrolment in graduate studies and international enrolment in graduate studies – Graduate students are an important part of the institutional research environment, and the ability to attract them from abroad is a good indication of how Canada’s higher education and research environment is perceived abroad.

Attraction and retention of researchers – Canadian universities’ collective ability to retain researchers and to attract researchers from abroad is one indication of how our research environment is perceived.

Co-authorship – Collaboration is now an essential part of a successful research environment. Co-authorship data provide one indication of overall trends in this area.

Private sector investments in university research – The ability of universities to attract funding from the private sector is indicative of how the university research environment is perceived by the private sector. Contract research and collaborative projects are important indicators of the linkages that exist between the two sectors.

International research funding – Measuring the combined ability of universities to obtain competitively-allocated research grants from abroad provides one indicator of the overall quality of the Canadian university research environment.

Second Order Indicators

Universities transfer knowledge in many ways, including the production of highly qualified graduates, publications, presentations, expert advice and consulting, community service and outreach, public policy engagement, commercialization activities and cross-sectoral partnerships, among others. Together, they lead to substantial benefits for individuals, communities and cities, provinces, regions, countries and the world.

Data are readily available in Canada and abroad for graduate degrees awarded, publications, commercialization activities and, to some extent, cross-sectoral partnerships, but not for measuring the results of the other types of knowledge transfer activities. Nevertheless, any accounting for universities’ contributions to the wider society must try to capture these contributions in qualitative terms where quantitative measures are not available.

Graduate degrees awarded – Degrees awarded at the graduate level are a major “product” of the university research effort, and are a good indicator of the results of public sector investments in university research and of Canada’s relative performance internationally.

Publications and Citations – While not without weaknesses, publications and citations data can provide useful indicators for comparing trends in national research output.

Commercialization – Used with care, data on revenues, patents and spin-offs can provide useful indicators of the overall level of commercialization of university research.

Cross-sectoral partnerships – Considerable knowledge transfer occurs through research collaboration between universities and other sectors, notably the private sector. Federal research investments help to create university capacity to engage in such activities.

Economic impact – While it is extremely difficult to show direct links between specific research investments and measurable improvements in the economy or quality of life, macroeconomic impact studies have been the basis for government investments in research for more than half a century and, given their total factor approach, continue to provide a sophisticated demonstration of the overall link between university research (and universities more generally) and economic growth.

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Introduction

In recent years, governments around the world have invested heavily in research – probably more than ever before – and more specifically, in university research. They have done so because of the importance of research to a country’s competitiveness and productivity and in recognition of the real economic and societal benefits that ultimately accrue to a country’s population as the result of a successful research effort.

These large-scale investments in research have been accompanied by increased expectations. Governments want to see the results of their investments and expect increased accountability in return for the large sums of public money invested in research. They also want to be able to assess their countries’ relative research performance in a fast-changing and highly competitive international environment. This is true in Canada, where the federal government and some provincial governments have made very substantial investments in university research over the past decade, and it is also the case in many other developed countries.

The development of indicators – and, more specifically, the identification of indicators relating to innovation – gained importance throughout the second half of the twentieth century. Individual countries, and more importantly the OECD, have been looking at these issues and trying to develop an appropriate “tool kit” of instruments and indicators to assess research performance. In parallel, we have seen the emergence of bibliometrics as an international tool to measure the outputs and quality of research.

The increased expectations regarding accountability for public investments in research, combined with a greater capability to collect, disseminate and analyse data, have resulted in increased use of research-related metrics in recent years. As a result, we have today a number of indicators that can be helpful in the assessment of the multiple facets of the R&D enterprise at various organizational levels. These indicators are used by firms, universities, sectors, provinces and national governments to aid in the assessment of their own research efforts over time or to inform comparisons with other organizations, institutions, countries, etc.

Nevertheless, these indicators – especially so-called “input” measures – do not fully meet the expectations of governments with regard to measuring the results of public investments in research and assessing progress toward measurable targets.

For this reason, governments and other organizations are taking a closer look at the use of indicators to help assess various aspects of research performance.¹ In particular, they are

¹ For example, Australia, the UK, the US and the OECD are all involved in large-scale exercises to review or develop indicators in relation to research and development.

looking for the best ways to measure the results and relative success of public investments in research, to understand the state of their national research efforts in an international context, and to inform public policy.

This paper discusses results-based measurement of public research investments, drawing on Canadian and international experience. It is not intended to provide a comprehensive inventory of indicators for measuring the results of research investments. Nor is it intended to provide an exhaustive assessment of such indicators. Rather, it proposes a practical approach to measuring the results of federal investments in university research at the Canada-wide level and provides a partial inventory of indicators currently in widespread use in Canada and abroad. It discusses some of the strengths and weaknesses of each of these indicators and sets out contextual information that should be taken into consideration in the use of such indicators.

It should be noted that while the emphasis in this paper is on measuring the results of federal investments in university research, it is not always possible to separate federal investments from other investments when assessing research results. Nevertheless, we know that the federal government is the primary external funder of university research in the country (almost half of external funding, or \$2.6 billion in 2005). Since the federal government began reinvesting in university research in 1997, these investments have clearly had a catalytic effect on other sectors, which have all significantly increased their investments in university research over the period. For example, several programs requiring matching funds from other sectors had a very positive impact on university research and on the whole research environment in Canada.² Consequently, it is reasonable to infer that on many of the indicators discussed in this paper, an important part of any progress over the past decade can be attributed to federal investments. At the same time, the impact of investments by other orders of government or sectors cannot be ignored.

A Practical Approach to Measuring Results

The traditional approach to assessing the state of the research enterprise, from the initial inputs all the way to results for society as a whole, is through the lens of inputs, outputs, outcomes and impacts, often diagrammed as follows:

Inputs → Outputs → Outcomes → Impacts

The *inputs* to research are generally measured by the investments made in the research process. Research input indicators are well-developed and widely used in most countries to set national targets, to measure progress, and to provide a tool for international benchmarking. Input indicators offer a relatively precise and comparable picture of the resources going into the research process. The use of Gross Expenditures on Research and Development, its breakdown by sector (Higher Education Expenditures on Research and Development, Business Expenditures on Research and Development) and their levels

² For a detailed analysis of how these investments have translated into tangible results, please see *Momentum: The 2005 report on university research and knowledge transfer* at www.aucc.ca/momentum.

relative to other data series (GERD to GDP, GERD per capita, GERD per researcher, HERD per faculty, etc.), are commonly used indicators that are relatively easy to generate.

Research *outputs* are generally treated as the direct results of research, such as research publications and citations, patents, licences and, perhaps, spin-off companies. Graduates who have acquired research skills through their own research projects or involvement in faculty members' research are also a very important output of the university research effort.

The *outcomes* of research often are defined as the more or less direct effects of research and its outputs, such as changes in government programs or public services, new products, improved production processes, etc.

Research *impacts* are generally understood as the socio-economic effects that research ultimately has on society in terms of, for example, economic impacts and improvements in quality of life. Broad macroeconomic impact studies are well-recognized and have formed the basis upon which governments have invested in research, particularly since World War II.

Input and output indicators are often used as short-term proxies for the eventual long-term impacts of research investments. While input and output measures are fairly well documented and readily available, the concepts of outcome and impact in relation to specific indicators are more problematic. Definitions are not always consistent; and the lines between outcomes and impacts are often somewhat blurry.

The main problem that arises as we move from research outputs to research outcomes and impacts is that it becomes increasingly difficult to link research investments and research projects with their ultimate results. Outputs can usually be linked to individual research projects. This may also be true of some research outcomes, but they are frequently the result of the interaction of multiple research programs combined with the expertise of highly educated and talented people.

The socio-economic impacts of research tend to be much more indirect. While some impacts can be directly traced back to particular research discoveries – e.g. the impact of the discovery of insulin on life expectancy and quality of life for diabetics – research impacts are more often discussed at an aggregate level in terms of, for example, competitiveness, productivity, standard of living and ultimately, quality of life where the links back to public investments and the research they support are more indirect, though no less important. In short, as we move further from outputs to impacts, the connections between specific projects and their individual effects are less clear, while a growing number of outside factors come into play. To quote one important source on the subject:

Macro-level econometric approaches to understanding the impacts of basic science on the economy suggest that there is a big, positive relationship between doing basic research and economic growth but are incapable of giving us enough

detail about which piece of science does what to let us choose between alternative scientific investments.³

The definitional and methodological challenges are real; and the complexities involved in measuring results certainly suggest a need for multiple measures and for the use of a combination of quantitative indicators and qualitative information, as well as great care in interpreting various measures and rigorous attention to the context in which the measures are applied. Both in Canada and internationally, a great deal of attention is currently being devoted, both by government agencies and university researchers, to improving our understanding of the impacts of research on society.

The challenges do not, however, provide a good reason to avoid demonstrating results for public investments in university research. Governments generally understand that the broad societal impacts of research are long-term, indirect and, hence, difficult to measure precisely. Nevertheless, they want to improve their ability to account publicly for large-scale investments of public monies in university research and in so doing, to demonstrate concrete, short-term results. They want to be able to define success in measurable terms and to be able to demonstrate measurable progress toward success as a consequence of public investments – and they expect universities to do their part in helping to define success and demonstrate results.

In this context, rather than trying to employ the traditional input/output/outcomes/impacts categories with all of their definitional and methodological challenges, it is practical to look at the results of public investments in two broad categories:

- *“First order” results in terms of the impacts of the investments on the quality and competitiveness of the university research environment.*

Many of the investments and initiatives undertaken by governments in Canada and other countries in recent years have been explicitly intended to enhance the competitiveness of their university research efforts and, in particular, of the university research environment. While a dynamic, competitive university research environment is not the ultimate goal of public policy in this area, governments have recognized that the quality of this environment is a determining factor in the ability of universities to develop and compete for research talent, to conduct quality research and to contribute to translating research findings into socio-economic benefits. This is why, in capturing the results of investments in university research, it is necessary to look first at the quality of the overall research environment in the country, and how these investments are helping make this environment dynamic and competitive.

- *“Second order” results in terms of the “products” of the university research environment, their transfer or translation to the wider community, and the ultimate benefits they bring to the wider community.*

³ Arnold, E. and K. Balazs, *Methods in The Evaluation of Publicly Funded Basic Research*, 1998.

The two categories are clearly inter-connected, as a quality research environment is a prerequisite for good second order research results; and a good record of second order results helps to attract the right resources (e.g. funding from all sources, talented researchers and students) and create the right linkages (e.g. collaboration with other sectors within Canada and collaboration with international research partners) to sustain and further enhance a quality environment.

General Observations on the Use of Indicators

Before turning to a discussion of some first and second order indicators, it is important to offer some general observations on the use of indicators in the public policy process.

- It is important to resist the temptation to search for the one and only indicator that would tell the whole story – the “magic bullet” indicator that would allow measurement of progress for each incremental dollar of public investment. Quantitative indicators are imperfect. When used in isolation, they offer a narrow and fragmented view of the world. Good practice involves the “agile” use of multiple, imperfect evaluation tools to reach policy-relevant conclusions.⁴
- Composite indicators should be used with caution. Such indicators can generate an unwarranted impression of accuracy and reliability if not carefully explained and placed in the proper context. Furthermore, no single composite indicator will ever be able to capture the entirety of the results of public investments in university research. Composite indicators are particularly problematic when weightings are applied to the data elements making up the overall indicator.
- Country-level indicators, which are the focus of this paper, do not take into account regional dimensions – for example, a national indicator that shows Canada doing relatively poorly internationally should not be interpreted as indicating that all regions within the country are doing poorly. As well, certain indicators, as we narrow their geographic scope, lose their significance statistically.
- Compared to research in the private sector or in government, a much larger proportion of university research in Canada is basic research. Consequently, university research requires a different mix of indicators to assess results – and demonstrating links between university research and ultimate societal impacts can be even more challenging. For example, we need to take into account the unpredictability of research results, which varies across disciplines and across sectors. If we look across the spectrum of research and development we recognize a continuous variation from a highly predictable engineering project to virtually unpredictable basic research.
- Despite the growing use of indicators in countries world-wide, and the increasing importance they hold in decision-making processes, indicators are only measuring

⁴ Arnold, E. and K. Guy, *Technology Diffusion Programmes and the Challenge for Evaluation*, Paper for OECD Conference on Policy Evaluation in Innovation and Technology, 1997.

what is quantifiable and therefore offer a limited picture of what they are assessing. Indicators are stronger when used in combination with qualitative information. Qualitative information will help capture aspects of research that, otherwise, would not be understood. Case studies that document the societal benefits that result from individual research discoveries are an important source of such information, and surveys of perceptions can serve to complement indicators that are based on widely available data from sources such as Statistics Canada or the OECD – e.g. the recent report published by the Council of Canadian Academies combined output measures with the results of a commissioned survey and other qualitative information.⁵

- Using qualitative information is especially important for the social sciences and humanities where the ultimate impacts of research are often more difficult to capture in quantifiable terms than in other science disciplines.
- When doing international comparisons, it is essential to keep in mind that data collected at the country level are rarely perfectly comparable with other countries. This can sometimes be attributable to methodological differences or differences in the structure of the systems in place. For example, the way research funds are attributed to the higher education sector is very different in the US and Canada, making it risky to make any comparisons based on HERD data for the two countries. Moreover, point-in-time comparisons rarely provide the kind of fulsome information that comes from comparing trends over time.

First Order Indicators

This section sets out several categories of indicators to measure first order results – i.e. impacts of public research investments on the quality and competitiveness of the university research environment as a whole in Canada. They draw on various traditional input indicators as well as a number of indicators that are specific to the university research environment. It would certainly be possible to set targets over time on a number of these indicators as well as measure the progress made towards meeting those targets.

1. Funding

Competitive funding of the four pillars of the university research environment – direct costs of research, indirect costs of research, infrastructure and research talent – is essential to create an internationally competitive research environment.

As noted earlier, such input indicators have been used extensively in Canada and abroad. While they are insufficient to meet growing government expectations for public accountability and results measurement, they are still an appropriate part of the mix of assessment measures for the research environment, particularly for the purpose of making international comparisons. They include such measures as GERD to GDP, HERD to GDP, and BERD to GDP.

⁵ Please see Council of Canadian Academies, *The State of Science & Technology in Canada*, 2006.

It is important, however, to keep in mind that even though they are widely used by many countries, these indicators are not perfect and not perfectly comparable. OECD countries follow the OECD's Frascati manual to construct surveys used to collect national data on investments in research, but differences in the way funding is allocated and various methodological variances can create data series that are not comparable. There are also issues surrounding data reporting in the OECD Main Science and Technology Indicators, including the use of the Purchasing Power Parity as an exchange rate. Obtaining data directly from statistical agencies in other countries is always a better alternative.

Data sources: Statistics Canada, Gross Expenditures on Research and Development for Canada; statistical agencies in other countries or OECD Main Science and Technology Indicators for international comparisons.

2. *Enrolment*

a. Enrolment in graduate studies

Graduate students are an important part of the institutional research environment. While developing their own research skills, they play an important supporting role in many research projects. In some predominantly undergraduate institutions, upper-level undergraduate students may play similar roles.

Overall enrolment at the Master's and PhD levels is one obvious national indicator of Canada's performance relative to other countries. Without the use of a survey instrument, it would be difficult to determine the degree to which undergraduate students are involved in supporting research efforts. The emerging use of the National Survey of Student Engagement is beginning to provide some additional indicators on the importance of research in undergraduate programs.

Graduate enrolment can also provide an important indicator for assessing how well we are doing in developing research talent compared to competitor countries.

Data sources: Statistics Canada; statistical agencies in other countries (ideally) or OECD for international comparisons.

b. International enrolment in graduate studies

Our overall ability to attract international students to our graduate programs is an indicator of how this country's higher education and research environment is perceived abroad.

Data sources: Statistics Canada; statistical agencies in other countries (ideally) or OECD for international comparisons.

3. Attraction and retention of researchers

The ability of Canada to retain its researchers and to attract researchers from abroad is a sign of how our research environment is perceived. In the 1990s, we were at risk of a major brain drain as researchers were attracted to research positions outside of Canada. In recent years, we have experienced a relative brain gain as we have been successful in attracting and retaining talented people.

Canadian universities' combined ability to attract researchers from abroad or from other sectors in Canada – often the best and brightest in their fields – is a sign of the quality of the research environment in Canada.

The Canada Research Chairs program is a good example of how federal investments in research have helped attract top researchers from around the world. Of the 1689 chairs awarded to date, 32 percent were repatriated or attracted from abroad.

Other indicators might include data on faculty attraction and retention, as published by Statistics Canada.

Data sources: Statistics Canada, results from the University and College Academic Staff System; Canada Research Chairs Program.

4. Co-authorship

Co-authorship data are derived from bibliometrics as an indicator of patterns of collaboration among researchers. They capture different types of collaboration (e.g. multi-authored articles; international, inter-provincial, inter-sectoral, intra-sectoral and inter-institutional collaboration) and help us to understand the overall level of collaboration in the country and whether it is increasing.

In fact, collaboration *is* increasing. For example, since 1980, Canadian researchers have significantly increased the amount of collaborative research in which they engage – both in absolute terms and as a proportion of the total research effort. This is true for most countries around the world, but even so, Canada is well-positioned, as was pointed out in AUCC's 2005 report entitled *Momentum*:

Canada's international research collaboration, as measured by the percentage of publications involving co-publication activity, continues to grow steadily and exceeds the world average. Canada has the highest rate of international co-publication with the U.S. – the world's largest producer of research – and is diversifying its co-publication activity through collaborations with researchers in Europe as well as emerging countries in Asia and in Central and South America.⁶

⁶ AUCC, *Momentum: The 2005 report on university research and knowledge transfer*, 2005, page 28.
www.aucc.ca/momentum.

While these bibliometric data are indicative of overall trends in research collaboration, they are not without weaknesses. In general, these weaknesses derive from the weaknesses in bibliometric data as a whole, which are described in more detail in a later section of this paper, as well as from methodological concerns regarding how co-authorship data are defined and collected.

Data source: *Observatoire des sciences et des technologies*.

5. Private sector investments in university research

Although investments are input measures, private sector investments in university research provide a good indication of how university research – and the university environment in which that research is conducted – is perceived by the private sector. Contract research and collaborative projects are important indicators of the linkages that exist between universities and the private sector. Such collaborations are becoming increasingly important in our global knowledge economy.

In recent years in Canada, we have seen the private sector increase its investments in university research despite decreases in its own research. These investments have almost tripled over the last 10 years to an estimated \$899 million in 2006. Research contracts, for their part, accounted for almost half of overall private sector investments in university research in 2004 (most recent year for which detailed data are available): \$365 million of the \$743 million in total.

It would also be relevant to track private sector investments in industrial chairs, as well as the total number of such chairs.

Another interesting measure to consider is the percentage of private sector research investment that goes to the higher education sector. In 2006, this proportion is estimated at 6.8 percent, one of the highest of all OECD countries and the highest in the G-8.

Data sources: Statistics Canada, Gross Expenditures on Research and Development for overall private investments in university research; Statistics Canada, Survey of Intellectual Property Commercialization in the Higher Education Sector for the research contracts; OECD, Main Science and Technology Indicators for international comparisons; NSERC and CIHR for number and value of industrial chairs.

6. International research funding

This is yet another input measure but again, it provides a good indication of the quality of the Canadian research environment by measuring the combined ability of Canadian universities to obtain competitively-allocated research grants from abroad. It indicates how effectively the Canadian university community is able to compete internationally to obtain research funding, and could therefore be interpreted as a measure of the overall level of competitiveness of universities compared to other countries.

For example, in 2004, Canadian universities were able to obtain \$65.2 million in grants and awards from the National Institutes of Health (NIH) in the US. This is close to 18 percent of total NIH research funding of \$352.6 million that went outside the US. Canada ranks second in percentage of such funding behind the United Kingdom.

Data Sources: National Institutes of Health or other international funding mechanisms.

Second Order Indicators

This section sets out several categories of indicators to measure second order results – i.e. the “products” of the university research environment, their transfer or translation to the wider community and the ultimate benefits they bring to the wider community.

Universities transfer knowledge in many ways and do so more than any other sector. Universities are the only institutions that link “the production of knowledge to the development, application and dissemination of knowledge production skills and capabilities. This significantly widens the number of potential knowledge transfer venues, very few of which are represented in the current indicator regime.”⁷

Universities transfer knowledge through the production of highly qualified graduates, publications, presentations, expert advice and consulting, community service and outreach, public policy engagement, commercialization activities and cross-sectoral partnerships, among others. While some of these activities are more prevalent or more widely documented than others, they all contribute to the successful transfer of knowledge to and from Canadian society. Together, these forms of knowledge transfer lead to substantial benefits for individuals, communities and cities, provinces, regions, countries and the world.

Data are available in Canada and abroad for graduate degrees awarded, publications, commercialization activities and, to some extent, cross-sectoral partnerships. However data are not readily available to measure results of the other types of knowledge transfer activities. Nevertheless, it is important to stress that these activities are a major part of universities’ contribution to the wider society and any accounting for universities’ contributions must try to capture these contributions in qualitative terms where quantitative measures are not available.

In short, in any discussion of the results of university research, we must not lose sight of the fact that quantitative indicators alone can never capture the full range of benefits that accrue to society over time as the result of the process of research discovery – whether major breakthroughs or the cumulative building of knowledge that more often characterizes the research process.

⁷ Hawkins, R. W., C. H. Langford, and K. S. Sidhu, *University research in an ‘innovation society’*, Paper presented at the Blue Sky II 2006 Forum held in Ottawa in September 2006.

1. Graduate degrees awarded

University graduates – particularly Master’s and PhD graduates because of their generally more intensive involvement in research – are a major “product” of the university research effort. They are also a primary means, and many would say *the* primary means, of knowledge transfer and translation. Consequently, the total number of graduate degrees awarded at the Canada-wide level is an important indicator of the results of public sector investments in university research, and of Canada’s performance relative to competitor countries.

Graduate degrees awarded can also be an important indicator of a country’s relative success in developing research talent.

Data sources: Statistics Canada; statistical agencies in other countries (ideally) or OECD for international comparisons.

2. Bibliometrics

Bibliometric indicators include the number of publications in scientific journals and the number of citations of these publications by other researchers. They also capture different types of collaboration (co-authorship) within and between sectors, countries, etc. as noted in an earlier section of this paper.

a. Publications

The number of publications in scientific journals makes it possible to compare national research output and to track progress over time. It also helps in the assessment of national scientific productivity. Data relating to publications are also broken down by disciplines and fields of research, allowing tracking at this level of disaggregation.

In Canada, the *Observatoire des sciences et des technologies* developed the Canadian Bibliometric Database, using the Science Citation Index, Social Sciences Citation Index and the Arts and Humanities Citation Index databases of Thomson Scientific.

Publication data are relatively easy to use and understand, and their relatively low cost makes them a very popular instrument for measuring the state of certain aspects of the research enterprise. Bibliometrics can be applied to various levels of the research enterprise (individuals, institutions, sectors, countries), and to a number of fields and sub-fields. However the more they are used for small-scale phenomena, the less they become statistically significant.

Publications count is generally accepted by the international community as a relatively good representation of research output. A country that invests heavily in its university research effort can reasonably expect that its research output as measured in terms of research publications will increase correspondingly. However, as with any other single indicators, contextual factors have to be taken into consideration – for example, if many

countries are making similar investments while the available pool of scholarly journals does not increase proportionately, a country may have to invest heavily just to avoid slipping in terms of numbers of publications.

As well, bibliometric data also have a number of weaknesses that need to be considered, including:

- Bibliometric data are heavily biased toward English language publications, which creates an over-representation of publications in English and an under-representation of publications in other languages. This creates particular concerns for the social sciences where publications in non-English speaking countries are most often in languages other than English.
- Bibliometrics only capture articles in scientific and technical journals, and exclude any other type of publication such as chapters in books, exclusively web-based on-line journals, etc. This is a particular problem for the social sciences where researchers often publish in other types of publications.
- Bibliometrics do not capture publications whose focus is on sub-national regions. Again, this has a greater impact on the social sciences where publications are often focused on issues that are more regional than national or international.
- There are a number of issues relating to the methodology for attributing an article to a field of study (cross-disciplinarity is a problem, for example).
- The use of bibliometric methods for the analysis and evaluation of research practices in the natural sciences and engineering is well established, but given the data problems noted above, their application to the analysis of the social sciences and humanities should be undertaken with greater care.⁸
- The comparison of scientific publications from different countries in the social sciences and humanities is “a hazardous exercise”⁹ for the reasons that are explained above.

With the caveats above, publication data can provide a number of useful indicators: e.g. trends in the number of publications, world share, publications per population, publications per faculty, etc.

Canada presently ranks eighth in the world in terms of number of publications (2004). Countries that are ahead of Canada are, in descending order: United States, Japan, Germany, United Kingdom, France, Italy and China. Canada was surpassed by China in 2001. Like China, India is also investing heavily in its university research enterprise and may well pass the current leaders in years to come.

Data sources: *Observatoire des sciences et des technologies*. Other data sources should not be used for Canadian publication data. The OST acquires the Canadian data from Thomson Scientific and “cleans” it in order to make it more accurate.

⁸ Larivière, V., Y. Gingras and É. Archambeault, *Comparative Analysis of Networks of Collaboration of Canadian Researchers in the Natural Sciences, Social Sciences and the Humanities*, 2005.

⁹ A number of articles have been written on this, but see especially Note no. 14 from the Observatoire des Sciences et des technologies, *An Overview of Canadian Research in the Social Sciences and the Humanities*, 2005.

b. Citations

Citations data – the indexing of citations in scientific and technical journals – are also derived from bibliometrics. Citations data are frequently used to measure the quality of research, based on the assumption that there is a positive relationship between the number of citations and the quality of a published work. Highly cited articles would be considered of better quality than articles that are poorly cited.

However, citations data do have technical problems and substantive conceptual problems.¹⁰ For example, citations data do not distinguish between positive and negative citations. Some weaknesses in citations data are directly linked to the weaknesses of publication data noted above.

Again with the caveats above, citations data can provide a number of indicators: e.g. world share of citations, share of the world's most highly-cited publications, average number of citations per paper, etc.

Data source: Thomson Scientific.

3. Commercialization Indicators

The increased focus on commercialization in recent years has resulted in a greater emphasis on identifying indicators that accurately assess how universities are doing in terms of commercialization, both over time and in relation to other countries.

There are two main sources of data on commercialization in Canadian universities: Statistics Canada's survey of commercialization in the higher education sector, and the Association of University Technology Managers' survey that is conducted both in Canada and the U.S. International comparisons of commercialization performance should be undertaken with caution. For example, in the case of the AUTM survey, which is conducted in both Canada and the U.S. following the same methodology, the response rate for Canada is far lower than in the U.S., and varies greatly from one year to the next.

a. Revenues from commercialization

In 2002, Canadian universities agreed to triple their collective commercialization performance by 2010, as part of the Framework of Agreed Principles on Federally Funded University Research between the Government of Canada and AUCC. The indicator developed for this purpose by AUCC, in consultation with Industry Canada, is called "Total Income from the Commercialization of Intellectual Property". It is the sum of income from intellectual property, cash dividends received by institutions and equity holdings, options and warrants cashed in by institutions, as measured by Statistics Canada. Equity held is not reflected in the measure, given market fluctuations and the

¹⁰ Arnold, E. and K. Balazs, *Methods in The Evaluation of Publicly Funded Basic Research*, 1998.

difficulty of assessing the value of these public and private holdings accurately and comparatively.

AUCC also monitors a number of other indicators that are not subject to the tripling commitment but that do, in combination with Total Income indicator, provide a more complete idea of how universities are doing on different aspects of commercialization. These indicators are operational expenditures on IP management, number of spin-offs, disclosures, new patent applications, new licenses and the value of industrial research contracts. Patent and spin-off indicators are discussed below and the value of industrial research contracts was discussed in a previous section (Private sector investments in university research).

In 1999, the base year for the tripling target, total income derived from the commercialization of university intellectual property was \$23.4 million. To triple this income, universities and their affiliated institutions will need to reach \$70.2 million or more from their commercialization activities in 2010.

As in the case of any such exercise that compares data on a single composite indicator at two end points, it is essential to put the indicator in context.¹¹ For example, if a university was to dispose of equity in a thriving spin-off company in a given year during the ten-year period, the result could be a significant “spike” in the national indicator for that year. What really matters is the trend over time and whether that trend indicates universities’ enhanced capacity to commercialize products and processes. As well, it should be emphasized that the indicator is only a partial proxy for the economic and social benefits generated by commercialization of university research.

Data source: Statistics Canada, Survey of Intellectual Property Commercialization in the Higher Education Sector.

b. Patents

Indicators related to patents include numbers of patent applications, patents issued and patents held. Overall, they can give an indication of the intent to commercialize IP and signify commercial value in an idea or invention. The rate at which institutions generate new patents is reflective of not only the viability of ideas and inventions but of the actions institutions are taking to realize the commercial potential of their IP.

Data source: Statistics Canada, results from the Survey of Intellectual Property Commercialization in the Higher Education Sector.

¹¹ While this is a composite indicator, and hence subject to the earlier words of caution in this paper about the use of composite indicators, it should be stressed that the data elements in this indicator are not subjected to arbitrary weightings.

c. Spin-offs

Historically in Canada, different universities have chosen different means to commercialize research discoveries, depending in part on their own circumstances. For example, some institutions, feeling that their ability to licence discoveries is limited due to their distance from major corporate headquarters, have opted to rely more heavily on the creation of spin-off companies. Consequently, in assessing overall commercialization performance, it is important, as noted earlier, to monitor indicators related to spin-off companies rather than relying on licensing revenues alone (or even the total income indicator in which licensing revenues are a major component).

The most obvious indicator here is the actual number of spin-offs, but because not all spin-offs are active, it is also important to monitor annual revenues from those companies as well as the number of people employed. The latter is particularly interesting in the sense that it demonstrates a direct economic impact of university research.

Between 1999 and 2003, the number of spin-off companies increased by 25 percent to 850. In 2002 (most recent data available), these companies employed almost 20,000 people full-time and generated more than \$2.5 billion in revenues.

Data source: Statistics Canada, results from the Survey of Intellectual Property Commercialization in the Higher Education Sector.

4. Cross-sectoral partnerships

A significant amount of knowledge transfer takes place through research collaboration between universities and other sectors, notably the private sector. While much of this partnership activity is funded by the industry partners themselves, federal research investments help to create the capacity in the universities to engage in this type of activity.

The current indicators in place are too broad to fully capture and appreciate these types of partnerships and the impact they might have at the regional, provincial and national level. Consequently case studies are essential to provide a better understanding of the types of partnerships that are in place and how they are translating into real results.

5. Economic impact

All of the second order indicators discussed above can help to demonstrate the results of federal investments in university research in terms of the transfer of knowledge into the wider community. However, they do not demonstrate in measurable terms the ultimate impacts of this knowledge transfer on Canadian society. As noted in the opening section of this paper, it is extremely difficult to demonstrate a direct link between specific research activity (and public investments therein) and measurable improvements in the economy or quality of life of Canadians. Nevertheless, it is possible to measure at a

macro level the economic impact of universities broadly, and the impact of their research activities more specifically.

A number of economic impact studies have been done at the regional level. These provide a good overview of how universities and their research activities can be economically beneficial for the region where they are situated.¹² However, the challenge lies in the fact that methodologically, these studies cannot be compared or added up to come up with a national figure.

One significant study to document the economic impact of university research at the national level has been done by Fernand Martin, an economist at l'Université de Montréal. He undertook an assessment based on available data and estimates for 2004. Dr. Martin estimated the dynamic impact of research activities at Canadian universities on national GDP to be about \$50 billion. The dynamic impact of university research on Canada's GDP is calculated by assessing universities' cumulative contributions to both the production and transfer of knowledge and technology and the enhanced productivity of human capital. Combined, these factors represent universities' cumulative contribution to total factor productivity – the economic growth resulting from increases in the efficiency and productivity of labour and capital.

The complexity of such econometric models makes it difficult to communicate their findings to the wider public. Furthermore, because it is impossible to isolate one factor from the others, it is not possible to use this approach to set the kind of specific results targets that governments desire. Nevertheless, as noted earlier in this paper, macroeconomic impact studies have been the basis upon which governments have invested in research for more than half a century. They remain important from a public policy perspective and, particularly given their total factor approach, continue to provide a sophisticated demonstration of the overall link between university research (and universities more generally) and economic growth.

¹² See for example: Association of Atlantic Universities, *Smarter Together: The Economic Impact of Universities in the Atlantic Provinces*, 2006; Montréal International, *Universities: Catalysts for the Development of Metro Montreal*, 2004.