Outcomes of University Research in Canada:  
Innovation Policy and Indicators in Triple Helix Relationships

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Key words: University-industry knowledge transfer, Indicators, Innovation policy

Abstract

This paper analyses Canadian Government attempts to encourage and measure commercialization of university knowledge for socioeconomic improvement. Universities are regarded as major, insufficiently exploited, repositories of knowledge. Here, paths by which knowledge can be transferred across institutional boundaries, and the various input and output/outcome measures are identified. Available Canadian data are evaluated and a detailed quantitative and qualitative study of one institution is presented. Three key issues emerge: 1) Current proxies focus on licensing and spin-off, and do not measure several important paths of knowledge flow. 2) Most readily available proxies are derived from aggregate data and are incapable of reflecting the idiosyncratic and path dependent nature of innovation. 3) If the goals and incentives of the actors in the triple helix are skewed or misinterpreted by indicators, universities and firms may engage in counterproductive activities. Simple additions to indicators that might avoid one measurable dimension becoming the policy driver to the detriment of the overall goals are proposed.

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Abstract

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1. Introduction

In 2002 the Government of Canada released an innovation policy report “Achieving Excellence” (Industry Canada, 2002). The report included a specific initiative with respect to the universities and “commercialization”.

Leverage the commercialization potential of publicly funded academic research. Support academic institutions in identifying intellectual property with commercial potential and forging partnerships with the private sector to commercialize research results... Academic institutions would be expected to manage the public investment in research as a strategic national asset by developing innovation strategies and reporting on commercialization outcomes... An evolving partnership would see universities more aggressively contributing to innovation in Canada, in return for a long-term government commitment to their knowledge infrastructure.
A particular novelty is an expressed expectation that academic institutions would “manage” the public investment for commercialization outcomes. Consequently, the government entered discussion with the Association of Universities and Colleges of Canada (AUCC), leading to a framework agreement on federally funded research (AUCC, 2002). Key points concerning targets, responsibilities, and evaluation include the following:

…Canadian universities have committed… [to] triple their commercialization performance… subject to… government investments. …Universities are responsible for the strategic coordination of the research efforts that will deliver these benefits… The parties also agree on… universities’ participation in the Statistics Canada survey of university commercialization… AUCC agrees to produce a periodic public report that demonstrates the collective progress made by universities… [in] knowledge transfer including commercialization and innovation.

Regarding the commitment to triple commercialization, the specific indicators implied are those of the Statistics Canada Survey of University Commercialization (Read, 2003). These include revenues and expenditures related to intellectual property (IP) management, spin-off companies, (and equity held in spin-off companies), invention disclosures, patent applications, patents awarded, new licenses and revenues from IP. Details of research funding are also reported (drawn from the agency’s Higher Education Statistics). Policies for university IP ownership, contracting and consulting are surveyed, but outcomes of such policies are not covered.

The agreement posits an intriguing form of a “triple helix” relationship. The universities’ association and the federal authorities have specified the relationship between universities and the third party, industry, assuming that the government should drive university contributions to industry and national interests. Moreover, the core of the relationship between university research and national benefit is presumed to be spin-off
firm formation and licensing of patents. Other relationships that include various forms of university-industry collaboration (contracts, consortia, and consulting) and the role of graduates are downplayed. Thus, while high-level policy may implicitly recognize the non-linear nature of innovation, the reality is that measurements are inherently based on a linear model of innovation. Usable statistics are recognized as, at best, proxies for measuring innovation (Freeman and Soete, 1997), yet there remains the danger that proxies de facto become goals in practice and shape the evolution of relationships.

The Canadian concerns are not unique. Similar interest in return on investment of university research is widely expressed and the literature on technology transfer through spin-off and licensing is extensive. Mowery et al (2004) review much of the US literature. In the UK, the Lambert Report (2003) emphasizes globalization and outsourcing of industrial research as an opportunity for universities. The “third stream” discussion (outcomes that concern use, communication, application and exploitation of knowledge) examines how government funding can support university-industry interaction. Molas-Gallart et al (2002) provide a comprehensive review of possible indicators of “third stream” university activity, supporting “top-down” development of a profile for application and recommends such development be carried out cautiously and experimentally. Following these lines of inquiry, this paper first reviews the various dimensions of university-industry interaction and critiques currently available Canadian indicators. These indicators implicitly follow a linear understanding of innovation, capturing at best incompletely the reality of knowledge exploitation. An in depth quantitative and qualitative study of university-industry relations in one institution is then presented. The case reveals the unavoidable imprecision in standard data collection (e.g. different spin-off and patent counts) and underlines the difficulty of disaggregating the most rewarding exchange or translation activities quantitatively. Finally, we offer a cautious “bottom-up” approach to short-term improvement of the basket of innovation indicators in Canada.

2. What is known about commercialization and university research
There is a substantial literature on innovation, commercialization and university research (e.g. Rosenberg and Nelson, 1994; Mansfield, 1998; Pavitt, 1998; Florida, 1999; Salter and Martin, 2001; Cohen et al, 2002; and Pavitt, 2004). Fortunately, there have been recent comprehensive reviews that simplify our summary (e.g. Reamer et al, 2003). We will assume that the objective of the government initiative is to stimulate economic and social benefit and not specifically to raise intellectual property revenues for the universities. Thus, the objective of commercialization involving university research is broadly interpreted as “innovation”, the process of bringing novelty into productive use (Schumpeter, 1934) that provides a net social benefit, what Baumol (1990) calls ‘productive entrepreneurship’ versus unproductive, rent seeking, behavior.

To understand any science-based innovation, a complex process must be traced. It is rare for a single individual to participate in both the discovery of basic science and in the development of commercial products. Individual scientists and engineers may enter and exit the process at any stage and there is much reflexivity in the paths of knowledge communication. As Reamer et al (2003) observe: *In each trajectory of science, technology and products, the process that unfolds is idiosyncratic, entirely dependent on context, individual and organizational capacities, and unique circumstances.* Similarly, a major study of British industry-university collaboration (Laursen and Salter, 2004) found that there was an overestimation of universities as a direct knowledge source for innovation: “*The interactions between universities and industrial firms remain largely indirect subtle and complex*” (p 1212). They further emphasize that managerial choice, industrial characteristics, and other heterogeneous factors play a major role in how knowledge is accumulated.

**Knowledge migration pathways**

In this complex environment, how does technology knowledge migrate across institutional boundaries? At least five pathways must be considered (Reamer et al, 2003):
1. **Cooperative research and development**,  
2. **Licensing or sale of intellectual property (IP) and spin-off**,  
3. **Technical assistance**,  
4. **Information exchanges**,  
5. **Hiring skilled people**.

Numerous surveys of the opinions of senior industrial research managers and their public statements (a current example is Mike Lazaridis (2005), founder of Research in Motion) have advanced the intuitively plausible opinion that hiring skilled graduates is most important. Highly qualified personnel are the principal product of universities, and play a major role in developing absorptive capacities in firms (Cohen and Levinthal, 1990). The importance of talent was reinforced in the study reported below of one university and in recent cluster studies in the same geographical area (Langford et al 2003, 2005). One of the few comprehensive studies of graduates, their businesses, and quantitative evaluation of the factors influencing their choices is the Bank of Boston study (1997) of MIT graduates over a century. It suggests, in agreement with Florida (1999), that innovative businesses choose to locate near universities mainly for the access to talent.

The impact of graduates is not yet explored by Statistics Canada (Read 2003), when the concern is “intellectual property commercialization in the higher education sector”. The overall aims of the agency’s science and innovation information program however, include study of “linkages” defined as “the means by which S&T knowledge is transferred among actors”.

Formal **collaborative activity** with universities is significant for industry. Both the largest and start-up business sectors have a high propensity for such collaboration (Fontana et al 2004; Cohen et al, 2002). Institutionalized collaborative research with universities is well developed in Canada. The Pulp and Paper Research Centre was founded at McGill in 1925 (Pulp and Paper Research Centre), and has been followed by industry-
sponsored centers on campuses across the country. A recent example is the multi-
million dollar University of Windsor/Chrysler Canada Ltd. Automotive Research and
Development Centre, the only research facility of its kind in North America (AUCC,
2005). Input proxies for some of these activities are embedded in reports of industry
investment in university research discussed below. Tripartite university-industry-
government consortia also exist, such as TRlabs (2005) in Western Canada where off
campus labs sponsored by universities, industries, the federal and three provincial
governments collaborate with five universities. Their specialties are coordinated with
local industry clusters and concentrations. Data on such independent ventures are not
captured in university funding reports.

At a next level, federal and provincial granting agencies have sponsored university
research chairs in collaboration with individual firms and industrial consortia across the
country. At present, these range from the study of risk to asphalt technology to quantum
computing. Some chairs have multiple sponsors. Chairs represent a long-term
commitment to collaboration that can facilitate “translation” at the university-industry
interface. Many university-industry collaborations focus on individual projects. These
may form the largest part of the industry research sponsorship reported by universities.
Many of these are stimulated by government participation and the matching funds will
be separated as government sponsorship in data.

Canada also has a major federal research sponsorship scheme to promote
collaborative research in areas of national importance, the “Networks of Centres of
Excellence” (NCE, 2005). This program fosters university research networks across the
country, with a requirement for active engagement with user partners from industry or
the public sector. Some reported university IP arises from research in these networks
and much of the investment is embedded in reports of federal funding of university
research, separated from industry contributions in the data. This program establishes
long-term networks that can foster extensive knowledge exchange among researchers
and with user partners. User partners can provide insight into the key problems and
affect research agendas.
Licensing and sale of IP and spin-off formation is the pathway on which the AUCC-Industry Canada agreement focused. It is also the central concern of the Statistics Canada surveys mentioned above. Output and outcome indicators are available for this area. Time series can be derived on a year-by-year basis from reports made by university IP managers to the Association of University Technology Managers (discussed below). An important aspect that our study of one institution confirmed is the extent to which IP transfer need not involve the institutional IP managers.

Finally, this brief review must mention the subtle pathways of information exchange and technical assistance. There is little current and systematic information on the Canadian experience. Recent American data comes from the Carnegie Mellon Survey on industrial R&D. Cohen et al (2002) summarize the analysis of this survey of industrial research managers with observations validating all the Reamer categories:

Contrary to the notion university research largely generates new ideas for industrial R&D projects, …public research both suggests new R&D projects and contributes to the completion of existing projects in roughly equal measure… results also indicate that the key channels through which university research impacts industrial R&D include published papers and reports, public conferences and meetings, informal information exchange, and consulting.

Cohen et al (2002) find that public research is critical to a few industries and important across much of the manufacturing sector. Cluster studies (Langford et al 2003, 2005) and analyses of patterns in one institution in Canada are consistent with the American data. Key channels may be outside the areas for which ongoing statistical data are available.

2. A critique of presently available indicators

Limitations on conceptualization of Canadian indicators
Following Jaffe (1998), we categorize performance measurement indicators as being concerned with *inputs, outputs and outcomes (impacts)*. The indicators can operate at three levels of representation: *measures of* (direct), *proxies for* (indirect), or *correlates of* (linked by some hypothesis) the phenomenon under analysis (Jaffe, 1998). Input measures have obvious limitations, particularly because they are concerned with intent rather than success. The awarding of competitive peer reviewed research grants is perhaps a good input proxy, but still a measure of promise and not a guarantee of output. Industry sponsorship investment can be used as an input proxy for industry-driven collaboration, the ‘market pull’ driver of knowledge transfer (Landry et al, 2002).

Output and outcome indicators deal with results. Publication, patent, and citation data are widely used and available output proxies. Available outcome (impact) indicators are commonly proxies for innovation, aligned to the pathway passing through technology licensing and spin-off creation. They suggest the linear model. Combined with input measures of R&D funding, output measures of publication and citation, outcome indicators such as licenses and spin-off formation are clearly suggestive of the linear model, an approach that has been widely discredited (Nightingale 2004). Unfortunately, this can produce a serious overall distortion. For example a recent review of the literature (Guena et al, 2003) reinforces that university-industry interactions are most important in forms where they require the reflexive interactivity captured by more modern models of innovation such as “chain-link” (Kline and Rosenberg, 1986), Mode 2 (Gibbons et al, 1994), and Fifth Generation (Rothwell, 1992) innovation models. According to Nightingale (1998), the linear model of scientific output leading to commercially viable technology fails to explain key features of innovation such as the importance of tacit knowledge, industrial science, non-science based technology, industrial differences regarding scientific requirements and why sometimes technology precedes the science that explains it. He further notes that the linear approach “reinforces a constricted view of the practical relevance of basic research by

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concentrating on direct and more easily measurable contributions, to the neglect of indirect ones".

Yet most outcome proxies are implicitly linear. For example, two of the most common measures, patent analysis and patent citation analysis, are based on the assumption that output proxies of explicit knowledge (patents and papers) lead to increased knowledge that eventually finds commercial benefits. Pavitt (1998) concluded that patents granted to universities provide only a partial and distorted picture of the contributions of university research to technical change (although patent citations may be more useful).

Emphasis on output and outcome measures relevant to one path of knowledge exchange can affect incentives. Incentives have long been recognized as influencing how individuals respond to organizational goals (Jensen and Meckling, 1974; Eisenhardt, 1989) and more recently the impact on knowledge transfer (Szulanski, 1996; Osterloh and Frey, 2000; Hall and Sapsed, 2005). Henderson et al (1998) for example found that during the last few decades, universities have been under increasing pressure to translate their work into privately appropriable knowledge, and in response, there have been notable increases in university licensing. They also found that university patenting greatly increased from 1968 to 1988, at a greater rate than university spending. However, during this period the quality of patenting may have decreased, begging the question that universities may have been patenting because it became perceived as a measure of success - ‘patenting for the sake of patenting’ rather than to protect intellectual property that is likely to be commercially viable. Other proxies of this path such as licensing, spin-off creations, and the establishment of university transfer offices may suffer from similar problems, where these proxies in practice become the goal.

Such phenomena have been conceptualized as institutional isomorphism. According to DiMaggio and Powell (1983), organizations engage in isomorphic behaviour in response to environmental pressures, with the aim of gaining legitimacy. Coercive isomorphism
“results from both formal and informal pressures exerted on organizations by other organizations upon which they are dependent and by cultural expectations in the society within which organizations function” (p.67). This includes explicit state regulations and laws, rules and standards imposed by non-governmental entities, as well as implicit pressures from stakeholders surrounding the organization. ‘Mimetic’ isomorphism occurs under uncertainty: “When organizational technologies are poorly understood, when goals are ambiguous, or when the environment creates symbolic uncertainty, organizations may model themselves on other organizations” (p.69). It may occur unintentionally and indirectly, or be explicitly, diffused by organizations. In both cases, organizations mimic other organizations that are perceived as both similar and more legitimate or successful – i.e. benchmarking, ‘herd mentality’, or to use Aldrich and Fiol’s (1994) title ‘fools rush in’. In this case, if enough dogma emphasized the importance of particular measurement proxies, both coercive and mimetic (i.e. response to the inherently uncertain nature of innovation) effects may lead to these proxies becoming the ultimate goal rather than being used for their intended purpose.

An ‘efficient market’ perspective would counter the ‘patenting for the sake of patenting’ and isomorphism argument by emphasizing that in the long-run industry will discourage inappropriate measurement proxies. However, this perspective regards firms as homogeneous entities, disregarding strategic choice, idiosyncrasies, context, individual and organizational capabilities and unique circumstances, all of which have been identified above as key factors in industry-university collaboration.

**Canadian Data Sources**

The data presently available to assess and benchmark Canadian university research have input and output proxy and outcome correlate components according to Jaffe’s (1998) categories. The often-emphasized input side includes the Canadian Association of University Business Officers (CAUBO) reports, used by Statistics Canada to derive university research expenditures. The inputs to university research are broken down
into contributions from government granting agencies, business and foundations. Illustrative data for selected leading institutions for one year appear in Table 1.

[Table 1 near here]

It is important to remember that the Canadian funding system is fundamentally based on project grants. The reports do not include general university funding (GUF). Faculty salaries aside, GUF is relatively unimportant in Canadian universities and does not function as a discriminator. Note that input data relates to outputs and outcomes only after time lags. The simplest lags are from funding to publication (4-5 years) and to citations indicating uptake (5-6) years (Crespi and Geuna, 2004). These lags do not take into account the complex interactions among distinct technical elements needed for industrial innovation (Valentin and Jensen, 2002). Thus, a minimum lag for the outcomes of government funded basic university research must be at least 4-6 years. The lag for work directly sponsored by a user will depend on the nature of the relationships of sponsor and researcher.

At the other end of the spectrum, the only systematic source of output and outcome data directly related to user involvement is the Association of University Technology Managers (AUTM) reports and the parallel, if less frequent, Statistics Canada surveys. AUTM reports include the proxies of invention disclosures, patent applications filed, patents awarded, licenses, and the outcome measures of revenue, active licenses, and spin-off firms. A sample of AUTM data from leading research universities in Canada appears in Table 2. The data sources prejudice indicator development in favor of the single path of a university technology patent being licensed to a user or serving as a basis for formation of a spin-off firm. An indicator (not available for Canadian Universities) that has been developed for other outcomes is the collection of data on citation of university publications in patents (Jaffe et al, 1993). Another is patterns of co-authorship between university scientists and those in other sectors. A study of the Canadian pattern of co-authorships (Godin et al, 1998) is dominated by university-hospital linkages. This probably reflects the close links of medical faculties and teaching
hospitals and consequently illuminates only a very special sector. Citation of academic papers in patents might be more revealing (Narin et al, 1997; Pavitt, 1998; Meyer, 2000, 2002). However, it is limited by the fact that citations appear in patents for many reasons. A significant number of citations are identified in only the patent drafting and application process and have little to do with the origins of the patent. In addition, only a fraction of patents are successfully exploited.

[Table 2 near here]

The available indicators of outcomes of Canadian university research are strong with respect to the pathway passing from input proxies through technology transfer offices licensing and spin-off creation, the pathway approximating the classic linear model of innovation. Table 2 shows AUTM data for fiscal 1997. It includes license revenues to indicate the success of innovations. Given additional data on the success of spin-off companies, we would have a very strong profile that closely approaches a direct measure of one path. Unfortunately, this can produce a serious overall distortion towards the linear model of innovation.

The weakness of indicators of the more subtle phenomena associated with the other four pathways undermines both theoretical and policy analysis. The available indicator of patent citation to academic publication is at best a correlate. At least in Canada, co-authorship across the university-industry interface is minor. The most direct proxy available is the level of industry sponsorship of university research, an input indicator. However, this surrogate deserves to be unpacked, especially if government policy primarily supportive of inputs to university research is to be linked to increased “commercialization” outcomes.
4. Quantitative and qualitative study of one institution

University faculty survey results

A questionnaire was sent to 1314 members of the full time faculty of the University of Calgary in 2004 in both hard copy and via email. The response rate was 18.4%, with the margin of error calculated to be 0.057 at 95% confidence. Thus, the data may represent opinions of the faculty overall, but will not be significant for breakdown by individual faculty areas.

The lead question was “what is the best way to achieve societal benefit for research?” 169 respondents selected publication in the open literature, 140 selected collaboration with an organization able to use their ideas, and 25 starting their own new business or venture. (Some marked more than one option.) In contrast, 41 (17%) reported that they had launched a business or other venture generating employment or revenue. It is probably significant that the largest fraction (31/41) came in similar numbers from medicine, science, engineering and social science, with the remainder distributed over six faculties. Consulting and services were the two largest activities with manufacturing making a significant contribution. As expected, distribution of employment levels resembled a power law. Four were in the 10-100 employee category (2 service, 2 manufacturing). Thirty-seven firms were reported to be currently operating, reflecting a high survival rate. An additional 20 responses indicated plans to launch a venture, and 34 respondents reported assisting the start-up of a venture. A need to complete a project and a need to exploit experience were reported significantly as motivating factors.

Thirty-one businesses and other ventures formed in the last decade were reported in this sample. AUTM data for “spin-off” creation report 16 firms from Calgary during this period. This underlines that the “standard pathway” via technology transfer agencies is not the unique source of university firm formation as has been reported by others (e.g. Meyer, 2002, 2003). In Europe, more patents with university contributions appear to be
owned by firms than by universities (Crespi et al, 2005). The “standard pathway” would appear to be the minority pathway.

The nature of economic benefits derived by firms or other organizations from university faculty research or consulting assistance was reported as follows.

- Development of a new product or service 20%
- Improvement of an existing product or service 17%
- Design of a new technological process or improvement of an existing one 20%
- Entry into a new market or expansion of an existing market 16%
- Design of a new administrative system or improvement of one 10%

All of the Schumpeterian (1934) categories of innovation are represented except the introduction of a new source of raw material. Faculty contributions are diverse. The respondents identified collaborative relationships with 85 different firms and organizations, 45 businesses and 40 with government and not-for-profits. The motivations reported by faculty members for collaboration with outside firms and organizations are also diverse (Table 3).

[Table 3 near here]

*University annual reports*

The University of Calgary provided aggregate data from the 2003 faculty annual reports submitted by all full time faculty members (1403 reports). These reports identified 81 instances of “technology transfer”. Leaders were:

- Engineering 35 0.28 per faculty member,
- Medicine 14 0.03 per faculty member,
- Environmental Design\(^2\) 7 0.28 per faculty member.

\(^2\) This faculty includes architecture, industrial design, environmental sciences, and planning.
It is commonly assumed that consulting is underreported, but 430 instances of consulting activity were reported. Intensive involvement was:

- Environmental Design 2.68 per faculty member,
- Kinesiology 0.81 per faculty member,
- Engineering 0.57 per faculty member.

Reports of patents, copyright registrations, trademark, and industrial design registrations number 101. Leaders were:

- Engineering 33 0.28 per faculty member
- Medicine 37 0.09 per faculty member
- Science 30 0.14 per faculty member

The University of Calgary technology transfer office reported filing 12 patent applications in 2003/04. The startling discrepancy indicates that formal, AUTM reported, technology transfer administration does not capture all IP protection activities, as has been reported in other studies (Meyer, 2002, Crespi et al, 2005). In these, patenting of university related inventions by firms exceed patenting by universities. Unfortunately, the Calgary reports do not name patent assignees.

Case study summaries

As noted above, innovation is “idiosyncratic, entirely dependent on context, individual and … unique circumstances”. In contrast, the available indicators are based on aggregated data that represents either a proxy or a correlate of the process leading to the desired goal. To approach a more realistic perspective, we conducted fifteen interviews with members of the university community who had been participants in well known innovative processes and with several industrial and community figures that have interacted with the university. The experiences canvassed included examples related to all of the five pathways mentioned above (see Table 4).

[Table 4 near here]
Three major research consortia were identified, two in science and one in engineering, all in pre-competitive research. The number of sponsoring companies exceeds ten in two of the cases. Research results are available to all sponsors with the exception of a few specific projects sponsored on contracts separate from consortium membership. Two produced outcomes primarily related to processes and the third contributed product technology. The scientists normally develop the research program options, but the sponsors set priorities among options. Knowledge arising is incorporated into internal company processes and it is difficult to disaggregate the contribution of consortium research to commercialization. However, one sponsor representative commented about an oil exploration technology; “one well pays for the entire cost of membership”. Sponsoring companies value the opportunities for contact with research students. The dollar inputs to the consortia form part of industry sponsorship reported.

The activity identified with the largest economic impact involved an engineering professor who held an endowed research chair. During his career he worked in industry and briefly in government before joining the university. His university work formed a key part of a process development that required large-scale resources for its completion, and thus a large part of the work was carried out in industry. It opened oil reserves of 600 million barrels to exploitation. However, it is not possible to assign a specific part of the return to the work in the university since the success depended on the integrated effort. The work in the university was clearly a critical component. The question is whether statistical proxies can recognize this type of university-industry outcome.

A successful case of licensing is medical. The inventor recognizes the contribution of the university technology transfer office in structuring the presentation of the invention, but the identification of the licensee depended on his important “accidental” contacts. As the invention process developed over the years, the technology transfer office played a critical role in management of the inventor-licensee relationship, facilitating the development of a good working relationship that contributes to knowledge flows that go well beyond the patents. The licensing company is multi-national and local economic
benefits are royalties. However, the inventor identifies the greatest social return to his work in the emergence of a “Calgary protocol” that has greatly simplified and reduced the costs of diagnosis of the related widespread condition. This benefit is first harvested locally.

The successful spin-off studied is a local biotechnology company created through partnership with major multi-national companies that invested and supplied technical and business assistance. The university technology transfer agency played a central role in structuring relationships and development of management. The university played a critical role by hosting the incubation stage of technology development, continuing well after company formation. The inventor remains actively involved. Key scientific personnel have been recruited locally. The inventor’s prior experience in industry contributed to recognition of the opportunity. The company currently has a market capitalization of $94 million and 48 employees.

The successful case of technical assistance is based on a unique facility that is valued worldwide in the oil and gas industry, Calgary’s major cluster. Tests in the facility play a role in implementation of one technology of enhanced oil recovery. This has direct impact on feasibility and cost for local and international implementations. The facility is also valued by local industry as a training site.

An important example of consulting centers on development of novel business practices by the holder of an industry-government co-sponsored engineering research chair. The novel practices improved contracting procedures for large-scale activities. In reporting to the government sponsor, one industry user, among many, identified work that produced capital savings of $10 million. The approach has been described in a book and is widely adopted. The City of Calgary is a representative public sector adopter. The chair is associated with a well-attended professional development program.

An engineering department combines a role in the infrastructure of a local cluster with recruitment of highly qualified personnel into the region and the cluster. The department
developed an early strength in an area linked to a local industrial specialization. The
departmental leadership undertook a focused campaign to achieve recognition in a
major international association that attracted university, industry and government
representatives to its conferences. This played a significant role in identifying Calgary
as a centre of the industry, and the use of Calgary manufactured equipment in the
university research publications has contributed to the region’s reputation. As the
reputation of the university program grew, it has been able to attract an international
cohort of outstanding research students, with approximately fifty percent remaining in
Calgary.

Consistent with the Bank of Boston study (1997), all of these examples explicitly
emphasized the importance of highly trained personnel. These cases also recognize the
importance of the intangible attribute of reputation. The proxies selected by the
government, however, do not recognize this university-industry outcome.

5. Implications

A key Canadian policy agenda is to improve social well-being through commercial
innovation. It is assumed that university knowledge can create a net social benefit and
productive entrepreneurship (Baumol, 1990). Universities have been identified as a
major, yet insufficiently exploited repository of knowledge (Landry et al, 2002). The
challenge is how to encourage productive knowledge transfer and accurately measure
it. In this paper, we discussed knowledge transfer paths, as well as input and
output/outcome measures now available. We identified three key issues regarding the
relationship between institutional knowledge transfer and measurement proxies.

First, current proxies and correlates do not measure several important paths of
knowledge flow, and the Calgary data show that some key metrics may not cover all
that they are presumed to report. Critically, a main contribution of universities is
qualified personnel diffusing knowledge into the workforce, and increasing absorptive
capacity once in the workforce.

Second, the most readily available proxies are derived from aggregate data, yet it is well
understood that innovation is idiosyncratic. It is also recognized that firms are
heterogeneous and concerned with appropriating benefits from their innovations.
However, the statistical treatment is homogeneous. What are the implications of
aggregated, homogeneous proxies for activities that are inherently heterogeneous?

Third, goals and incentives determine how individuals respond. If the proxies are
skewed or misinterpreted, universities and firms may engage in unproductive activities
such as 'patenting for the sake of patenting', rather than for appropriate reasons such
disseminating knowledge that is likely to be commercially viable appropriately.
Furthermore, there are major differences between industrial and academic incentives.
Industry typically seeks competitive advantage, generally accepted as being derived
from unique, valuable and difficult to imitate assets and capabilities (Barney, 1991).
Heterogeneity and appropriability are important (Teece et al, 1997), with the goal of
increasing shareholder value. Academics seek peer recognition, and thus may lack
interest in appropriability. How policy aims to reconcile these different incentives, and
how university assessment procedures will be changed to reflect better institutional
knowledge transfer remains unclear (Molas-Gallart et al, 2002). Policy-makers in this
context are seeking net social gain through knowledge commercialization. However,
policy makers are also constrained to provide policies that are fair and accessible to all
firms (i.e. homogeneous). While they may recognize firm heterogeneity, they are
required by their mandate to play by homogeneous rules.

Although problems with performance measurement are well known, in practice there
remains the danger that the proxies ultimately become the outcomes/impacts. In the
Introduction, we describe the goals articulated by the Canadian Government, but these
are in fact measurement proxies. This problem links with the implicit assumption of a
linear model of innovation, appealing only for its simplicity and access to available
statistics. Are the broader, yet downplayed forms of university-industry collaboration (contracts, consortia, consulting and role of graduates) being discouraged because linear proxies are driving policy? In the long term, inappropriate government proxies may not influence industry, if one assumes that markets will discourage inefficient behavior. However, institutional isomorphism may occur if the wider knowledge base (in this case policy and academia) propagates the importance of the proxies – i.e. if there is enough dogma, industry may follow suit. This is particularly likely under highly uncertain circumstances, as is the case for much innovative activities. The result is that we may get what we measure, rather than encouraging university knowledge commercialization to maximize net social benefits.

6. Conclusions: Improving indicators

The immediate need is to find indicators that can be simply implemented and widely accepted that function as proxies or correlates for the other four paths of the university-industry knowledge exploitation. Of presently available indicators, an input measure, industry investment in university research is probably the best proxy for path 1 (university-industry cooperative R&D). The time lag between expenditure and output does need to be addressed. This industrial sponsorship indicator could be substantially and readily improved if universities would report industry sponsorship broken down into:

1) consortium membership contributions,
2) ongoing contributions (not endowments) to chairs, and
3) renewal project sponsorship of the same university group.

This would identify the strongest university-industry connections (Landry et al 2002). In fact these three proposed sub-indicators might also be useful correlates of effective information exchange and effective placement of skilled people. The types of interactions in these categories are the ones that allow development of translation skills,

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3 One university research officer regards this sub-division as practical.
and our interviews repeatedly emphasized the benefit to industrial partners of access to research students as a part of research collaboration. The creation of these three sub-indicators is appealing as an immediate step to improve the Canadian situation. Further qualitative research is required to validate the suggested correlations and the degree of their comprehensiveness.

In 2004, Statistics Canada held a meeting on commercialization, measurements, and indicators (Earl et al, 2004). The discussions recognized that the agency’s survey of earned doctorates does shed some light on the human resource dimensions and could be expanded. As well, enhancement of the existing National Graduates Survey could be illuminating. Initiatives in this direction could add substantially to proxies for knowledge transfer through skilled graduate mobility. The direction is promising.

In conclusion, university-industry interaction indicators supplementing the study of “linear” technology transfer is feasible in the short term while indicator research continues. The benefit would be avoidance of one measurable dimension becoming the sole driver of policy to the detriment of the overall goals. Directions for indicator development suggested here do leave the pathways of special facilities and consulting yet to be addressed. Caution will still be needed to keep the complexity and heterogeneity of innovation and commercialization in perspective.

Acknowledgements
The Centre for Innovation Studies conducted research related to this paper for the Office of the Vice-president (Research) at the University of Calgary. We thank the university for support. The opinions expressed here are the authors’ and not necessarily those of the University. We also acknowledge provision of data from the Academic Annual Reports. We thank University Technologies International for access to AUTM data.
References


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Freeman, C and Soete, L., 1997. The Economics of Industrial Innovation, MIT, Cambridge MA, pp 1-27.


TABLE 1: Inputs to University Research, 1999-2000 (CDN$000). Source: CAUBO

<table>
<thead>
<tr>
<th>University</th>
<th>Governmental</th>
<th>Non-gov't donations, grants and contracts</th>
<th>TOTAL INCOME</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Federal Gov't</td>
<td>Provincial Gov't</td>
<td>Other Provinces</td>
</tr>
<tr>
<td>Dalhousie</td>
<td>33,020</td>
<td>5,973</td>
<td>149</td>
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<tr>
<td>McGill</td>
<td>87,010</td>
<td>27,184</td>
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<tr>
<td>McMaster</td>
<td>54,180</td>
<td>14,284</td>
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<td>Queen's</td>
<td>36,292</td>
<td>8,813</td>
<td>81</td>
</tr>
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<td>U of Toronto</td>
<td>146,709</td>
<td>57,881</td>
<td>138</td>
</tr>
<tr>
<td>Waterloo</td>
<td>30,501</td>
<td>15,071</td>
<td>300</td>
</tr>
<tr>
<td>Western</td>
<td>39,345</td>
<td>10,509</td>
<td>0</td>
</tr>
<tr>
<td>U of Alberta</td>
<td>81,017</td>
<td>59,293</td>
<td>5,830</td>
</tr>
<tr>
<td>U of Calgary</td>
<td>46,076</td>
<td>35,428</td>
<td>74</td>
</tr>
<tr>
<td>UBC</td>
<td>79,031</td>
<td>17,959</td>
<td>1,134</td>
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</table>

These data were provided by the Office of research Services, University of Calgary
Table 2: Data for selected universities from AUTM Survey, 1997
(Ranked by gross licensing revenue.)

<table>
<thead>
<tr>
<th>Institution</th>
<th>Year of 1st 0.5 FTE</th>
<th>Year of 1st 0.5 FTE</th>
<th>Total Sponsored Research (000 US$)</th>
<th>Invention Disclosures</th>
<th>Patent Applications</th>
<th>License &amp; Options Executed</th>
<th>License &amp; Options Executed</th>
<th>Gross Licensed Revenue (000 US$)</th>
<th>Legal Fees Expended (US$)</th>
<th>Legal Fees Reimbursed (US$)</th>
<th>US Patents Issued</th>
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<tbody>
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<td>U. Alberta</td>
<td>1987</td>
<td>94,676</td>
<td>85</td>
<td>44</td>
<td>34</td>
<td>3,053</td>
<td>41</td>
<td>360,899</td>
<td>102,921</td>
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<td>UTI U. Calgary</td>
<td>1985</td>
<td>72,250</td>
<td>72</td>
<td>13</td>
<td>31</td>
<td>2,074</td>
<td>59</td>
<td>304,946</td>
<td>304,419</td>
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<tr>
<td>U Toronto</td>
<td>1980</td>
<td>205,721</td>
<td>112</td>
<td>60</td>
<td>31</td>
<td>1,606</td>
<td>53</td>
<td>271,895</td>
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<tr>
<td>U British Columbia</td>
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<td>99,009</td>
<td>100</td>
<td>52</td>
<td>19</td>
<td>865</td>
<td>59</td>
<td>686,361</td>
<td>593,738</td>
<td>18</td>
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<tr>
<td>U Waterloo</td>
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<td>15</td>
<td>8</td>
<td>14</td>
<td>845</td>
<td>31</td>
<td>89,858</td>
<td>28,027</td>
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<td>Queen's U</td>
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<td>34</td>
<td>36</td>
<td>5</td>
<td>556</td>
<td>19</td>
<td>429,783</td>
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<tr>
<td>McGill U</td>
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<td>125,148</td>
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<td>15</td>
<td>311</td>
<td>30</td>
<td>434,127</td>
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<td>N/A</td>
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<tr>
<td>U Montreal</td>
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<td>126,579</td>
<td>28</td>
<td>22</td>
<td>26</td>
<td>309</td>
<td>11</td>
<td>125,679</td>
<td>35,132</td>
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<tr>
<td>McMaster U</td>
<td>1987</td>
<td>55,180</td>
<td>15</td>
<td>1</td>
<td>5</td>
<td>295</td>
<td>53</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>U Western Ontario</td>
<td>1995</td>
<td>50,563</td>
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<td>10</td>
<td>16</td>
<td>46</td>
<td>16</td>
<td>57,787</td>
<td>N/A</td>
<td>5</td>
<td></td>
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</table>

These data were provided by University Technologies International (UTI), Calgary.
<table>
<thead>
<tr>
<th>Reason</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monetary reasons</td>
<td>20</td>
</tr>
<tr>
<td>Advancement of science</td>
<td>19</td>
</tr>
<tr>
<td>Need to apply knowledge to practical applications</td>
<td>10</td>
</tr>
<tr>
<td>Complementary assets</td>
<td>9</td>
</tr>
<tr>
<td>Train/support students</td>
<td>8</td>
</tr>
<tr>
<td>Need to exploit expertise</td>
<td>6</td>
</tr>
<tr>
<td>Identification of market opportunities</td>
<td>4</td>
</tr>
</tbody>
</table>
**Table 4:** Case study results.

<table>
<thead>
<tr>
<th>Knowledge pathway</th>
<th>Type of example identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative research and development</td>
<td>• major research consortia&lt;br&gt;• direct participation in a large scale industry project</td>
</tr>
<tr>
<td>Licensing or sale of intellectual property (IP) and spin-off</td>
<td>• successful licensing to an established firm&lt;br&gt;• spin-off with a university scientist involved</td>
</tr>
<tr>
<td>Technical assistance</td>
<td>• services from a unique facility</td>
</tr>
<tr>
<td>Information exchanges</td>
<td>• consulting&lt;br&gt;  o contributing to the development of effective practices&lt;br&gt;  o working with the infrastructure of a regional cluster</td>
</tr>
<tr>
<td>Hiring skilled people</td>
<td>• in all cases, some form&lt;br&gt;• recruiting research associates internationally who remain in a local cluster</td>
</tr>
</tbody>
</table>