Measuring the Impact of University Research on Innovation

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1. Introduction

A summary list of the reasons universites engage in research can probably serve present purposes without detailed analysis:

1.1 advancing disciplines at the world frontier of emergence;
1.2 maintaining and enhancing professional competence;
1.3 configuration and generation of knowledge for strategic purposes;
1.4 enhancing societal capacity for research, innovation, and critical analysis (research training);
1.5 maintaining an open channel to the world knowledge system;
1.6 informing and enhancing the quality of undergraduate education.

The relation of these activites to an innovation system can be identified with **outcomes** that flow from these activities. The viewpoint of this paper is that *a framework for evaluation can developed around outcomes.* Such a framework will be the most usful for identification of *the role of universites in the innovation system*. One limitation that this view imposes will be that the measures discussed will not include those used to select particular research initiatives (e.g. projects) for sponsorship. That issue has already been well analyzed by various federal and provincial research sponsoring agencies. A second limitation is that only secondary attention will be given to input measures. It is not in doubt that these will continue to be collected. The present view is that these measure the scale and scope of activity in a jurisdiction and have only indirect impact on outcome. Their role in public policy is not negligible. An insufficient level of investment can doom any attempt to achieve quality outcomes, but investment is not in itself a measure of outcome. It should be stated immediately that the interpretation used does cover, under the outcomes commanding the attention of students of innovation, undergraduate education and cultural development.

The notion *technology transfer* tends to dominate policy discussion with respect to university research and the innovation system. The underlying conception of the innovation process that drives the language of technology transfer appears to be the linear model of innovation. Sometimes this is explicit, sometimes only implicit. Since there is general agreement that a linear model of innovation is unsatisfactory, analysis of the impacts of university research on the innovation process needs to go beyond the usual conception of technology transfer. Two anecdotal notes serve to introduce the point. It is interesting that most surveys of executives do not identify universities as a major source of inputs to innovative efforts (customers and suppliers dominate). In contrast, bibliometric studies of patents suggest the importance of university science to such indicators of formalized innovative activity as patents. The relationships are subtle.

The chain link model (OECD, 1994) offers a promising alternative framework. (See Figure 1.) It provides room to analyze indirect couplings and it does not limit attention to discovery. The name *chain link* is intended to remind us of the multiple feedback loops. This allows us to think of the university contribution intervening anywhere in the process.

The first step toward analysis of outcomes of university research is to analyze the pathways of the interactions of the Canadian university research system with its environment so that mechanisms of influence can be identified. Figure 2 suggests that university research is a node in a network with at least eight important links. The two large boxes on the left and right, development of highly qualified personnel (including undergraduate education) and contribution to the world knowledge system, are commonly recognized. Technology transfer is much discussed recently. The other five have received less attention. Each deserves some analysis.

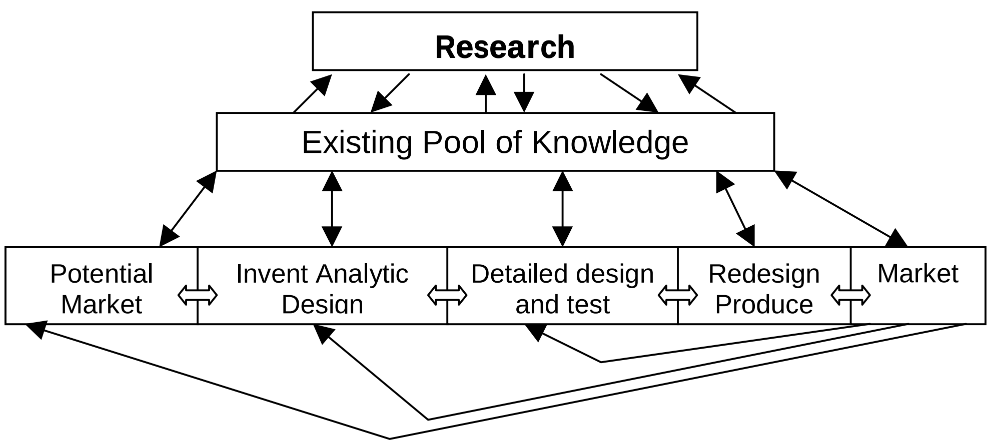

Figure 1. The chain link model of innovation.

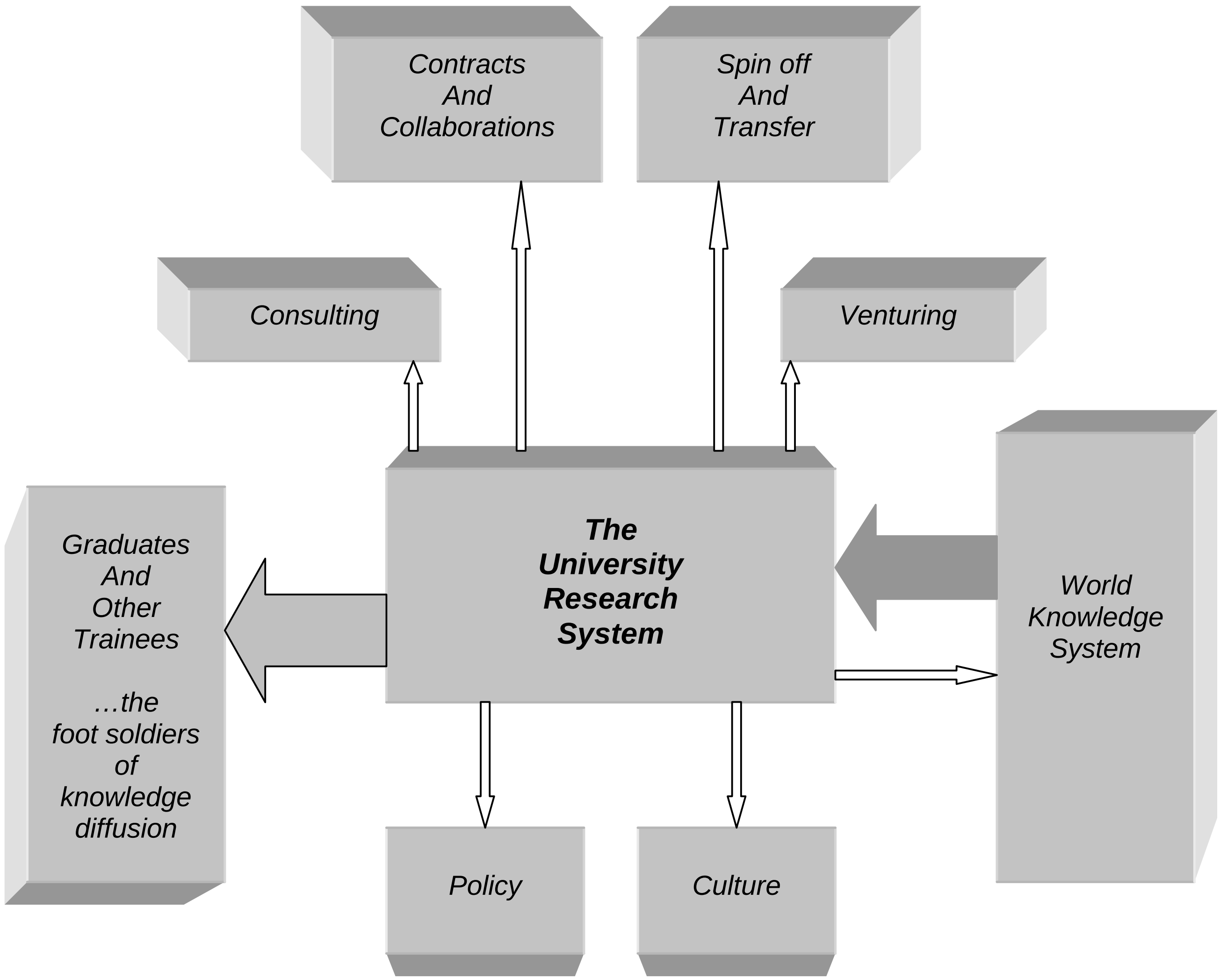

Figure 2. Linkages of the university research system.

2. Linkages of the university research system

The best understood links of the Canadian university research system are to the world knowledge system. The most often recognized but less analyzed are linkages through graduates and other trainees. The linear model of innovation already suggests the existence of the linkages classified as transfer and spin-off where the consequences of specific university research efforts influence innovative activity in other spheres through exploitation of the research results. Venturing is a distinct activity from spin-off as that term is usually employed. It is the establishment of business ventures based on the professional profile derived from university experience rather than specific research projects. Contracts and collaborations are specific university links with industry or government organizations. Consulting is an activity engaged in by a majority of university faculty, sometimes paid, and sometimes not paid. University faculty also contribute to shaping policy and culture through contributions that are in part consulting or volunteer work and in part communication through non-scholarly media.

2.1 Links to the world knowledge system – the intelligence function.

About 4.5% of the publication output of research institutions worldwide is contributed from Canadian institutions. Publication, with associated informal communication, is the bloodstream of the scholarly dialogues and critiques that convert research into reliable knowledge through the emergence of consensus (Ziman, 1978). It is clear that Canadian universities are not a dominant voice in the world system. Nevertheless, participation by Canadian researchers is quite important to other outcomes of university research in Canada. Through contribution to the world dialogue, Canadians earn a place at the tables where consensus emerges and gain a deep appreciation of current knowledge. Universities become a reservoir of contemporary knowledge that can be exploited by other sectors in Canada (commonly by people movement) to fuel a knowledge economy and enrich culture. Metaphorically, university researcher functions as an **intelligence agency** for Canada, gathering information from around the world and making it systematically available. The observation of a geographical correlation of firms patenting and university papers cited probably illustrates this function (Narin et al, 1995).

2.2 Highly qualified personnel.

A popular slogan among university technology transfer officers is that "knowledge transfer is a contact sport." The slogan underlines that effective communication for innovative use is not limited to the explicit knowledge of the written R&D report. It must include *tacit* knowledge. The most effective path for this knowledge flow is movement of people. This can simultaneously transmit both explicit and tacit knowledge, creating opportunities for the socialization processes (Nonaka and Takeuchi, 1995) by which tacit knowledge is communicated. Both research students and undergraduates (who participate mainly in classroom, not laboratory, experiences) can be influenced by the university research mission. Flows of graduates are easily identified, but it is less clear how to assess their impact in private and government sectors or the degree to which their university experience has included contact with research[1]. In addition, there is a research-training component in the experience of research associates, temporary

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[1] A very recent OECD appraisal of university education in Denmark remarks, once again, that it is difficult to detect the influence of research on the experience of first year students.

faculty, and technicians that needs to be accounted but does not show in graduation statistics.

2.3 Venturing.

A study of economic impacts of research at the University of Calgary (Chrisman, 1994) indicated that the launch of new commercial or not for profit ventures by university faculty is relatively common (~200 in twenty years at Calgary). Most of these were not what is usually understood by the terms “spin off” or "start up" company or “technology transfer”. Therefore, we introduce an additional term, venturing. These ventures flow from an opportunity arising out of a faculty member’s accumulated professional and research experience rather than from one particular discovery or technology package. The venture results from a growing recognition of a gap in the economy and/or society that can be filled by an activity based on the professional competencies that a faculty member has developed. The emergence of the venture is not influenced by the university technology transfer agencies because the process that leads toward the venture is “sub-terranean”. Venturing has received very little attention despite its major role. Venturing may be one of the most important external outcomes of university activity.

2.4 Consulting.

The Calgary economic impact study (Chrisman, 1994) emphasized the large role played by expert consulting, both paid and unpaid. There is high consistency between the view of this process from university faculty and from their clients. Using job creation as the measure of economic impact, clients of university consultants identified consulting as responsible for more than 15% of job creation attributable to university activity. If the impact of formal “on campus” projects such as Calgary’s *Venture Development Clinic* is added, consulting in one form or another accounts for almost half of identified job creation. It is likely that job creation parallels contributions to innovation (*vide infra*). In another study (Unrau and McDonald, 1995), it was found that consulting has a significant impact on policy formulation in both public and private sectors.

2.5 Contract research.

Contract research and collaborative projects are a significant factor. They promote direct communication between researchers in universities and researchers in government and industry sectors. The extent of knowledge exchange (both ways) is sensitively dependent upon the nature of the relationship. Longer-term relationships and ones of a program rather than short project character have greater impact because they allow for development of means of translation between the distinct milieus. Thus, long term activities including industrial research chairs and research consortia are usually the most productive.

2.6 Spin-off and technology transfer.

The terms spin-off and technology transfer are used here in the specific sense of formation of a new enterprise, or licensing to an established firm, based on specific outputs of a research program such as a patentable technology or a focused technology package. Careful reading of the literature suggests that this is a usual usage. The development exploited must be based on activity carried out formally in the university. The Chrisman study suggests that it is a factor comparable in economic impact to consulting and to contract or collaborative research, *but it is not more important.*

2.7 Policy analysis and formation.

A major impact of research done in universities is felt in policy analysis and formation in both public and private organizations. The study by Unrau and McDonald (1995) found that more than 70% of faculty members participated in external policy formation over the two-year period surveyed. A similar survey conducted in Quebec reached parallel conclusions. In general, clients shared the same perception of the impact of faculty contributions that the faculty members held. The policy advice had outcomes, frequently innovative.

2.8 Artistic culture.

Most universities would wish to include creative activity of an artistic or similar character within the domain of research. Some Quebec universities use the title “Vice recteur à la récherche et à la création” for their senior research officer. In most communities, this activity of universities plays a quite significant role in the cultural life of the community (Park, 1998).

3. The nature of research activity.

A critical feature of the emergence of the contemporary “knowledge economy” is the rise of a new style of knowledge creation. This style is a problem and team rather than discipline and investigator oriented mode. It is transdisciplinary. It often gives pride of place to configuration of knowledge over discovery. Yet it clearly reflects knowledge creation. It has been called “mode 2” (Gibbons et al, 1994). The better understood “mode 1” responds to the dynamics of disciplines and focuses on discovery at the surface of emergence of the discipline. Both modes are essential to the complex of research outcomes, but most of the indicators that are currently favoured in assessment are much more responsive to mode 1 than to mode 2. In part this arises from the fact that mode 2 knowledge production includes problems of such character that that no single corporate body in our society can any longer satisfy its knowledge need internally. Knowledge creation is becoming a more collaborative activity. The complex dynamics of consortia create difficulties for measurement. Yet, it is exactly those complex consortia that are the drivers of mode 2 knowledge creation.

In academia, there is a strong tradition of sharing knowledge. The product of research is seen as common property, but great credit goes to the originator holding publication priority. The owner of knowledge is not identified in mode 1, but the creator is celebrated. In mode 2, ownership may find a locale, but creation is hard to place. Objectives are institutional more than individual. The team is central. This implies a measurement asymmetry. In mode 1, creation appears to be easily measured[2]. In mode

[2] There is a danger for understanding of innovation in the scientific community's rule that credits discovery only to the "first through the gate". If there are multiple discoverers, as seems to be

2, it is less readily localized. Measures of mode 2 activity are badly needed. Measures will need to estimate quality as well as quantity. This presents an additional problem. As Gibbons et al (1994) argue forcefully, the measures of quality in mode 2 knowledge production are not the same as measures of quality in mode 1. Among other differences, mode 2 quality evaluation must take full account of the non-technical dimensions of the solution to a problem.

4. What is measured?

4.1 Outcomes and proxies

The present paper advocates a clear decision that the measurements relevant to university participation in the innovation system (measurements that do not face the need to predict the research future in the way a grant selection committee must) are about **outcomes**. Yet, it has been said, “many measures of outcomes are indicative only”. This can be read as an excuse to measure only inputs and outputs, but perhaps, the wrong “excuse” is adduced. During the work of the Alberta task force that proposed the current research “key performance indicators”, the greatest problem confronted by the members was identification of **databases** which would allow measurement of the aspects of performance sought. It rapidly became clear to the task force that **proxies** would be central to any system of indicators[3]. Continuing *emphasis* on measurement of indicators of inputs and outputs is justified to the extent that many can serve as **proxies** for **outcomes**. It is, then, necessary to identify and justify the proxy relationships sought. In some cases this is fairly straightforward. In others it is subtle in the extreme and great caution is required.

Of course, the point is not new. In the US, the Government Performance and Results Act (GPRA) of 1993 mandates that every agency prepare a strategic plan and then regularly assess its performance relative to that plan. The GPRA process distinguishes between outputs and outcomes. Outputs are the direct products of the agency. Outcomes are the effects or consequences that the program is intended to have. Indices used in the GPRA process include proxies for outcomes and beyond that the weaker concept, correlates. Table 1 shows some of the structure used in GPRA (Jaffe, 1998).

Table 1
Conceptual framework for Outcome Measurements

Concepts	Proxies	Correlates
Broad advance of knowledge	Papers, citations, peer review	
New products	Patents, citations	Licenses, royalties, product announcements, sales
Income growth	Benefit/cost ratio, rate of return	New firms, induced investment
Productivity improvements	Measured productivity growth	

common (Merton, 1973), the scientific 'first" may not be the most useful actor in an innovation system.

[3] I thank Mr. Robert W. Martin, chair of the task force, for these insights.

Health, environment, etc	New drugs	Emission levels
Cooperation and knowledge flows	CRADAs[4]	
Excitement about science		Science news articles

Notice that the table is not complete. Jaffe was unable to identify significant proxies in every case and even the correlates can be weak. For example, judging excitement about science by an accounting of science news articles would earn the label mentioned above, "indicative only". If straightforward statistical measures are to be incorporated into indicator schemes, it will be necessary to be clear about the **outcomes** for which they function as statistically “robust” **proxies**. For example, the Alberta task force judged that success rates in peer reviewed national granting council competitions would be one reasonable proxy for the degree to which Alberta institutions were connected to the world knowledge network and could deliver the outcomes dependent on that linkage. That is, grant awards are seen as the measure of the peer review evaluations., and those evaluations estimate contribution to the world knowledge system.

4.2 Technology transfer studies

If we examine recent statistical research in Canada, we find that researchers producing data on the linkages of the university system remain confronted by the serious limitations of the available databases despite some major efforts. Statistics Canada (1998) has a five year plan for development of an information system for science and technology. It is only in since 1998 that we have had access to the Statistics Canada survey of intellectual property commercialization in higher education. This document covers, in the main, only one of the eight pathways of influence of university research as the report acknowledges.

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> *…the impacts of other contributions are more diffuse. Scientists and technicians are trained for participation in the labour force, ideas are generated and published, and collaborative activities involve business, government, and international working groups* (Statistics Canada, 1998a)

The report also states that universities hold $22.5 M in equity in their spin off companies that number 366. The Calgary study, suggesting 200 ventures in 20 years, hints at the limit on looking in isolation at “spin-off and start-up” as defined by the survey. Moreover, a different method of accounting could identify equity values of $25 M in a single university in comparison to the survey report of $22.5 M summed over all responding universities. (Is the appropriate definition book value or market value?)

The Statistics Canada effort measures a number of important quantities. These include numbers of firms, survival of firms, university equity holdings in firms, licensing revenues, numbers of licenses and domestic vs. foreign revenues. If the data can become complete and reliable over time, the Statistics Canada approach will provide

[4] CRADA = Cooperative research and development agreement. In the Canadian university context, we might substitute Industrial Research Chairs and U/I Consortia.

information on all but one of the obvious quantitative issues of technology transfer. The data do not address job creation. Some surveys have attempted estimation of job creation. There is a fairly robust methodology, an example of which is the methodology used in the assessment of the U.S. Small Business Centers Program (Chrisman, 19XX).

The report for AUCC, *Approaches of Canadian universities to managing and commercialization of intellectual property* (ARA Consulting and Brochu, 1998) deals with the general problem of successful measuring.

> *There is a need for a much more inclusive (and more complex) metric than the amount of royalty and licensing returns to the university, or the sales revenues or cost savings to industry, or the number of spin-off companies.*
>
> *One must include other measures such as amount of industrial research funding attracted, financial investments made in companies that use IP, technology transfer from the movements of human capital, impacts on the local economy, etc. Much remains to be done (in Canada and elsewhere) in the development of appropriate indicators to measure successful knowledge flows.*[5]

One can hardly quibble with this eloquent statement of the problem, but there is something lacking. The language still derives from the authors' assignment. They were asked to assess "technology transfer". The term retains the unidirectional vector sense of the linear model of innovation. Examination of the chain link diagram at the top of this document reminds us that "research" (by a university or other autonomous agency) does not need to lie to the left (temporal precursor) in the innovation process diagram. It lies in a relation mediated by the pool of existing knowledge that can intervene or be drawn upon at any stage of the innovation cycle. It is not necessarily the initiator. There is, for example, no *a priori* reason to believe that the specific accomplishments of Canadian scientists that can be "commercialized" play a larger role in the impact of Canadian universities on the Canadian innovation system than the contributions of the "intelligence function". Canadian scientists participate in the world knowledge system and "bring home" critical components of "the existing pool of knowledge" for use in Canadian innovation.

4.3 Bibliometrics

Another major study related to university research is a bibliometric measurement of knowledge flows (Godin, Gingras, and Davignon, 1998). Using the share of papers published by Canadians in a field compared to the share that field commands of publication worldwide, the study is able to identify areas of Canadian specialization. This is probably quite appropriate for university research since publication is the main goal. It suggests that the Canadian specialties are Earth Science and Biology. Data from **citation impact** could be added to give a good proxy for the degree to which Canadian science is connected to the world knowledge system. Citation impact is used in the Alberta research performance indicators. The bibliometric study also explores the degree of interaction between universities and other players in the innovation system by examining addresses on co-authored papers to find collaborative publication. A further indication of the linkages to the world knowledge system emerges in the frequency of

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[5] Notice the mix of outcomes themselves and proxies. The authors are speaking to the realities of measurement.

international collaboration. It is also seen that the university sector is a major collaborator with the all other sectors in the domain of research published in the open literature. This is significant and probably a correlate of several forms of university linkage, but it is clear that much of what is important to innovation is not reflected in publication in the peer reviewed scientific literature.

4.4 Peer review

One of the continuing foci of evaluations of university research, including the outcomes, has been *peer review* to an international standard. From the UK quadrennial research evaluation exercise to Finnish efforts, international standard peer review has been a central element of what is measured (OECD, 1997). What outcome does it usually represent? Clearly, it is most often, given the peers chosen, a proxy for the effectiveness of the connections to the world knowledge system. It measures the capacity of the domestic research institutions to contribute to disciplinary discovery and its associated outcomes in both the human resource and knowledge flow areas (See sections 2.1 and 2.2). These are important but the usual peer review processes lead to emphasis on the CUDOS value system (Ziman, 1994) of academic science, which has an Achilles heel in the degree to which the traditions of science celebrate the “heroic” individual discoverer. As the sociology of science has known for some years (Merton, 1973), multiple discovery is much more the rule than is usually acknowledged. The reason for the heroic tradition probably has more to do with a socialization process that promises “fame” to entrants to the scientific community as the reward for originality. Thus, peer review tends to be skewed to recognition of individual accomplishment. Outcomes of value to innovation may not be so sensitive to who was "first across the line". (First adopters are not always the successful adopters.)

The defining question for peer review is 'who is a peer'? There is a growing tendency to open the peer review process to “experts” from outside the value system of academic science. The NSERC bulletin, *Contact*, carries regular calls for identification of panel members from outside academia. This is an important development. It may be leading toward construction of peer processes much more closely related to “mode 2” knowledge production. The definition of quality may move toward "mode 2' metrics (Gibbons et al, 1994). Clearer characterization of the key components in interdisciplinary/intersectoral collaborations and the factors favouring successful outcomes are needed for success in this enterprise.

4.5 Graduates and other trainees.

The largest group of individuals who are influenced by university research activity is the cohort of university graduates. The ones for whom the influence of research activity is most readily traceable are those receiving graduate degrees. Consequently, important indicators can be constructed based on the experience of recipients of Masters and Doctoral degrees. The National Graduates Survey, conducted by Statistics Canada with HRDC sponsorship is the key existing tool. It currently explores employment rate, employment type, job satisfaction, and satisfaction with educational experiences. The survey is conducted approximately every four years and surveys graduates two years after graduation. (The study of the class of 1990 was supplemented by a follow-up survey of 1990 graduates in 1995 to determine changes between the second and fifth career year.) The results are analyzed in detail, for many specific areas of study, in the

"Job Futures" publication of HRDC. The employment rate and job satisfaction items are important indicators of successful transfer of skills formed in university research environments that should serve as proxies for intensity of contribution to innovation. The linkage between university program and "discipline" of employment is more problematical. It is certainly not obvious that the optimal outcomes are obtained by avoidance of migration across "discipline" boundaries.

A number of institutions conduct exit surveys of their own graduates. These can be illuminating. They may offer an opportunity to develop proxies or correlates for the propensity to innovate over the broad student population, not just thesis students. Research is needed on the nature of questions that would elicit valuable information. A critical problem is the degree to which studies can evaluate value added. (There is a cynical observation that: "Harvard specializes in making silk purses from silk purses".) The Centre for Educational Research and Assessment at Guelph has reviewed outcome measures identified with change in knowledge, values, and skills[6]. All of the institutions that attempt to measure these outcomes use self-assessed questions in exit surveys.

5. What might be measured?

5.1 Outstanding issues.

The summary of what is measured indicates that significant progress has been made recently in measuring outcomes of formal "technology transfer" (where the university stands at the head of an innovation chain) and of institutionally managed spin-off. The measurement and analysis of the involvement of Canadian universities in the world knowledge system is well established through peer review and bibliometrics where well analyzed proxy relationships exist for outcomes internal to that system. However, there is much less accomplished in identifying the paths by which innovation is affected. The input is understood and the output characterized, but the linkage to outcome is difficult. The other difficult task, assessing the role that university training plays in the innovation system, is being meaningfully addressed through the graduate surveys. Other initiatives already suggest ways that might expand understanding of the effects of university experience as correlates of the propensity to innovate. The present measurements address three of the eight linkages of the university research system identified in Fig. 2.

Putting aside for the moment the question of the role of graduates, the Calgary study of economic impacts suggests that well over 50% of the economic impacts are not covered by the two linkages through formal "technology transfer" and spin-off. It is likely that a similar conclusion should be drawn with respect to innovation outcomes. University cultures are distinct from those of other sectors. There is little reason to undertake the translation process required to move knowledge in the reservoir of the university system unless there is a problem to be solved. Such problems are commonly ones solved innovatively. Thus, a strong correlation between university economic impact and contributions to the innovation system are to be expected. Needs exist for focused measurement of the roles of consulting, contract research and collaborative programs,

[6] See http://www.css.uoguelph.ca/cera/PSE/OUTCOMES

and venturing. Measurements should be sensitive to policy and cultural innovation as well as economic.

5.2 Contract research

Contract research is most commonly measured in terms of the input metric of dollars of contracting by an institution or a unit. This metric may stand as a proxy for an outcome if it is measured over time and used to indicate not simply the level of activity, but its acceptability to clients. In this respect, the numbers may be interpreted in a fashion analogous to interpretation of sales of a firm. An extremely valuable supplement to input measures are surveys which assess client response over several dimensions in comparison to only the self-appraisal of the consultants.

Use of the income-input measure does skew reporting to give greater prominence to high cost efforts, e.g. engineering or medical clinical trials. Important efforts in policy research areas may only slightly perturb overall income statistics and artistic commissions are likely to go unreported. An ironic footnote is that in areas that are not laboratory intensive, government agencies, even those with an interest in university performance such as CMEC, have a propensity to contract with individual scholars rather than with the institutions. This inhibits reporting.

Reporting of contract research income is one part of the collection of data on research which is presently organized for Canadian universities through the Canadian Association of University Business Officers (CAUBO). There is an increasing recognition that not all institutions use the same definitions in the data reported to CAUBO. For several years, the Canadian Association of University Research Administrators (CAURA) has worked on standardization of reporting. Recently, the problem of non-standard reporting has caused problems for the Canada Foundation for Innovation. This problem is not limited only to reporting on contracts.

Even as reporting improves and breakdown of statistics by discipline groupings is addressed, we will not learn as much from input measures as is desirable. Survey research, probably involving sampling of university faculty could enhance our understanding. It might explore the goals and duration of relationships, the character of the outside organization and the functional areas that seek university support, the perceived outcomes from the university side, and, most importantly, client perceptions of outcomes.

A special problem, which is here classed with contracting, is the work of research consortia. Anecdotal evidence about the impact of consortia can be found in the descriptions of the winners of the Conference Board of Canada - NSERC program of awards for University/Industry Synergy. Consortia range from the programs that arise around industrial chairs, through industry specific research centres like PAPRICAN labs at McGill and Alberta Sulfur Research, Ltd. at Calgary, to multi-university collaboratives illustrated by TRlabs (telecommunications research) in the west. To some degree the provincial centres of excellence and the Networks of Centres of Excellence present the consortium problem. Clearly this list includes the growth sector of the university research effort in Canada.

A consortium pursues a research program of value to groups of clients. The shared activity often belongs to the "precompetitive" domain. It is consequently difficult to trace the ultimate use of the research product. Some larger organizations have developed sophisticated tools to evaluate economic impact, but these are not practical for smaller or more localized units. One area where information from the consortia is readily obtainable and of considerable significance for impact on innovation is information about the level of transfer to consortium sponsor employment of graduate students working in research projects of the consortium.

In the areas of outcome which contractual research (especially through consortia) encompasses, a very interesting issue is the discovery of proxies for knowledge flows among sectors. Bibliometrics has made an important contribution (Godin, et al, 1998). To the extent that researchers from other sectors join with university researchers in publication, bibliometric analysis can be applied to identify linkages between university research and that of collaborators by analysis of co-authorship in the publication databases. Some of the paths of knowledge flow can reveal themselves in these patterns of co-authorship. Unfortunately, knowledge on the move leaves the printed page of the scientific journal early in its journey through the innovation system. Much that is important to knowledge flows is not recorded by formal publication.

5.3 Consulting

Consulting is unquestionably an important and pervasive activity. When asked, substantial majorities of faculty acknowledge being engaged in consulting, and the majority of the work may be unpaid. It is very important to distinguish the phenomena from simply "moonlighting activity". A good deal of consulting goes on through institutionalized clinics on business, law, etc. At present, it seems difficult to collect detailed information on a comprehensive basis. The situation may not change without a shift in faculty evaluation that makes consulting a more positive factor in performance appraisal, so that the motivation to track it carefully exists for all faculty members. The Statistics Canada survey cited above has asked institutions to report how much information on consulting activity they collect from their faculty. Improvement is clearly needed.

An accounting of activity alone is not an entirely satisfactory surrogate for desired outcomes. If activity is the only measured parameter, at least statistics on repeat activity should be collected to give some proxy for client valuation. The most satisfactory methods to evaluate the outcomes of consulting are based on survey research. Surveys need to be based on careful sampling plans and must include validation of consultant self-appraisal using client interviews.

5.4 Venturing

Venturing is an outcome that is hard to measure, and about which available statistics are hard to interpret. Where reporting has been attempted, completeness has been extremely variable and definitions have differed. A part of what is here included as venturing is included as a subject in section 5 of the Statistics Canada survey *Intellectual Property Commercialization in the Higher Education Sector, 1998.* The inclusion is a consequence of the distinction that is made in that survey between start-up and spin-off companies. The term start-up is limited to new firms that are dependent upon licensing the institution’s intellectual property. New firms that sponsor further research in the university with a view to ultimate commercialization or that offer services previously offered in institutional departments are classed as spin-off but not start-up. This curious usage does not exhaust the reasons that faculty launch ventures (either for profit or non-profit). It does, however, serve to clarify the point that one term (e.g. spin off) is insufficient to characterize the phenomena. Beyond the definitional problem, surveys answered by university industry liaison offices (ILOs), or the increasingly popular arms length technology transfer organizations, will not capture a large share of the activity.

A university professor retiring early from the science faculty to take up a photography career is not an example of the sort of venture where the university experience can be said to play a significant role in innovation. In contrast, an engineering professor whose consulting activity moves to the level that a firm with employees emerges is an example of venturing. It is noteworthy that the Calgary study reported two cases where management professors were involved in the launch of innovative manufacturing firms. These did not use university science or engineering, but university management talent. Would these cases be "spin-off" by the Statistics Canada definition? If so, would the data collection path have captured them?

As the term venturing is used here, the recommended approach to measurement is survey research based on carefully designed sampling. Venturing is sufficiently widespread, diverse, and random in incidence that it is unlikely to be reliably represented in systematic collection of institutional data. The important questions will turn on the way in which a venture reflects the professional experience and knowledge configuration gained in the university setting.

5.5 Further notes on policy analysis and artistic culture

A major difficulty confronting measurement in this important area is that so much of the formal research done in support of policy formation is sponsored in relatively informal ways and is not easily extracted from institutional records. Often, sponsors prefer a direct relationship with a scholar and seek to leave the institution out. Some institutions refuse to count activities so sponsored. Moreover, some of the important contributions are volunteer efforts that escape even individual faculty member annual reports. Data from indicators for contract research may contain some of the desired information. Similarly, studies of consulting will expose parts of this activity. In several institutions, survey research has proved revealing.

Records of exhibitions, artistic commissions, major performances, productions, concerts, works of fiction, and other creative activity are frequently available from the annual reports of faculty. Summaries of these activities can form a valuable adjunct to description of innovation. Artistic creation is hard to quantify. However, highlight summaries prepared by the units involved can aid assessors to gain an appreciation of outcomes. The artistic outcomes have a definite connection to innovation.

In both the policy and culture areas the work of “popularization” carried out by university faculty is important and contributes to innovation. Just as with artistic creations, quantification is difficult. However, summaries of institutional highlights in trade book production, media presentations, and journalism can serve as a valuable aid to assessment.

6. Conclusions

This account indicates that substantial progress has been made in the last few years in the measurement of the role that universities can play in innovation systems. However, it reveals that most of the measurement relies on proxies and correlates that have been subject to only limited test for robustness and that are subject to significant problems with completeness. As well, they are weak with respect to a number of the linkages of the university system. The direction toward improvement appears to recommend a modest immediate goal. A series of carefully defined survey studies of well selected, manageable sample size, faculty populations could give a much clearer picture of the mechanisms by which university activity influences innovation systems. These studies should give priority to the important areas where current analysis is weakest. Contract research, consortia, consulting, and venturing are candidates.

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