University research in an 'innovation society'

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I. Preamble

In monitoring and measuring the performance of national and regional innovation systems, the role of universities in stimulating innovation has become one of the most hotly contested issues. It has long been accepted that the university can be an abundant source of new ideas that eventually may transfer into the market. However, there has been much debate about the actual paths of such transfer, its direct economic significance and about the modalities by which it occurs. Econometric arguments can be made that academic research has a high ROI (e.g. Mansfield 1991, 1998). Others argue that "commercialization" of university research by entrepreneurial universities (Etkowicz, 1983) is an essential economic driver. This latter view is countered with arguments that the greatest value of university-based research lies in training highly qualified personnel and providing basic scientific research and advisory capabilities (Nelson 1966; Cohen *et al* 2002; Feller 1989; Feller *et al* 2002).[2]

However, in the increasingly results-oriented research funding climate in most OECD countries, universities are being called upon more frequently to justify public investment by demonstrating that new ideas are finding their way into commercial applications more quickly and in increasing quantities. Arguably, these pressures have been multiplied by encouragement for the direct exploitation of publicly-funded research by universities (e.g. the Bayh-Dole Act in the US). The result has been an explosion of technology transfer centers, a new priority to create spin-off companies and an increasing interest by governments in the higher education expenditure on R&D (HERD) figures. Accordingly, many

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[2] In most cases this point is conceded even by strong proponents of the university role in R&D. Mansfield, for example, does not disagree that this is a key university function.

universities have come to see knowledge transfer to industry as a way to leverage increased government funding of research.[3]

Problematically, it has always proven difficult to demonstrate the overall economic impact of publicly-funded, university-based research (Salter & Martin 2001). Moreover, most of the empirical evidence that has been produced to date tends either to question assumptions about the extent or significance of commercialization and spin-offs, or to suggest that the relationship is fragmentary, inconsistent and highly context dependent (Mowery *et al* 2001, Nelson *et al* 2001; Cohen *et al* 2002, Sampat *et al* 2003).

In this paper, we will suggest that there is yet an even more challenging problem. The conventional statistical definition of university-industry knowledge transfer (i.e. what we count and do not count) is tied to a very narrow conceptualization of innovation as a phenomenon; one that is oriented almost entirely to the production and application of new technology. As a consequence, evidence for the performance of university-industry knowledge transfers is gleaned more-or-less exclusively from indicators associated with the inputs and outputs of natural science and engineering laboratories. Our contention is that the indicator regime, so oriented, misrepresents and very probably underestimates the role and value of university research in the innovation process.

We begin our discussion by re-conceptualizing the dynamics of innovation in terms other than the production of technology. Instead, we explore these dynamics in the context of an *'innovation society'*, a heuristic device for visualizing innovation not just in terms of individual new inputs – be they technologies, methods, organizational forms etc. – but in terms of the *assimilation and absorption* of factors like these by social groupings of various kinds, such that the result is observable change in behavior or practice. In other words, we propose to define and assess innovation in terms of what actual changes it produces in the socio-economic fabric, rather than in terms of any specific contributing factor, technological or otherwise.

Inevitably, this leads us away from currently dominant production-oriented perspectives and forces us to confront the problem of how *demand* for innovation is expressed and fulfilled. Specifically in the university-industry knowledge transfer context, we propose that demand factors determine the kinds of knowledge that industries require in order to be able to respond to the complexity of the socio-economic environments into which they seek to place the goods and services they develop and/or produce.

Within this framework, technology becomes but one of many knowledge streams that must come together in order for innovation to occur. By making no

[3] For example, the Association of Universities and Colleges of Canada has openly proposed a 'deal' by which government research funding would double in return for a tripling of knowledge commercialization by the universities (AUCC 2004).

assumptions that technology is necessarily a primary and causal factor in innovation, we gain far more scope for understanding the role of technology in a much more nuanced way, particularly as an interdependent or even dependent factor in innovation. From this standpoint, the scope of university-generated knowledge that might be directly relevant in any specific innovation context is broadened considerably.

Adopting the information society perspective, we next construct a critique of the current indicator regime for assessing the university contribution to the innovation system. We propose that the university occupies a unique and pivotal position in the innovation society. Universities do produce and sometimes directly exploit knowledge, but increasingly many other institutions both collaborate and compete with universities in this endeavor (Hicks 1995). But no other institution links 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.

The innovation society framework allows scope to investigate a much fuller range of university-generated knowledge inputs that are or may become relevant to innovation. Many of these knowledge transfers do not emanate from basic or applied science laboratories. Instead, they may come from a diverse array of social, life and management sciences and in some cases also from the arts and humanities. Their role is to enhance our ability to understand, influence and exploit the socio-economic milieu in which innovation occurs. Building upon previous work by several scholars that suggests how we might be able to assess these inputs more systematically in an innovation context, we illustrate that the innovation society creates a variety of roles for many different kinds of knowledge and that no particular form is necessarily dominant. We propose that in order to understand the innovation process in more of its complexity, we need to begin valorizing and measuring more types of knowledge inputs.

Finally, with reference to case studies and examples of possible demand-sensitive metrics we illustrate how different indicators could be developed that allow us to investigate the nature and modalities of university knowledge transfer more adequately. We conclude that the extent and significance of university knowledge transfer into the innovation process is likely much greater, more direct and more diverse than demonstrated in the current indicator regime and that it is possible within the conceptual framework of the innovation society to refine our understanding of the knowledge transfer process.

II. The 'Innovation Society' – defining the socio-economic context for university knowledge transfer

The simple linear model of innovation – wherein innovations are seen to flow from the transfer of basic scientific knowledge into applied research (R&D)

contexts and thence into market applications – has been discredited by most scholars. All subsequent models have stressed the interactivity and reflexivity between basic and applied science and between technology and markets – commonly expressed in terms of feedback loops and interdependencies. Nevertheless, there remains a heavy emphasis on investigating innovation in the virtually exclusive context of technology – indeed, post Nelson & Winter (1977 & 1982) the focus has been predominantly upon the dynamics of technology production and adoption in firms.

Freeman (1994) suggests that the reasons for the historical emphasis on *technical* change have been methodological, reducing the broad and complex social parameters of innovation to a more manageable set of inputs and outputs for economic modeling purposes. Certainly he is correct, but economics is fundamentally a production-oriented science. Thus, technology is attractive as a surrogate for innovation because it is a measurable industrial output. It is not surprising therefore that for indicator purposes 'innovation' has been conceptualized almost exclusively as '*technological* innovation', irrespective of the nature or extent of the role actually played by technology in this process.

Thus, most of the indicators in current use (particularly patents, R&D data and publications data) are oriented in effect, to *invention*. This despite admonitions from virtually every significant scholar of innovation phenomena since Schumpeter that invention and innovation are different (even if related) and that the analytical parameters of innovation are far broader than technical change and indeed in many cases may not be related to technology at all.

Crucially for a more holistic 'societal' conceptualization of innovation, virtually none of the indicators in current use gives any adequate explanation for what *motivates* the innovation process in the first place. Most scholars would now agree that innovation does not occur simply in response to expressed demand for goods, which was the basic assumption of neo-classical economists who saw innovation merely as a new production function. But this is no excuse for the almost complete lack of systematic empirical investigation of demand factors.

Exploration of the demand issue – which might help explain the much broader social factors that make innovation possible – largely has been either sidelined altogether or confined to interpretive case studies. Over time, however, stimulated most recently by an intensified interest in service innovation, a growing band of social scientists has been taking the idea of a social calculus of innovation more seriously, dispelling the idea that innovation can or should be explained mainly in terms of conventional manufacturing-oriented factor inputs (Lancaster 1966; Cornwall 1977; Miles 2000; Stetterfield 2002; McMeekin *et al* 2002; Tidd & Hull 2003; Cowan *et al* 2004).

For producers, the motivation to innovate may be simply to gain advantage over other producers. But this may not correspond to how end users or consumers formulate demand for products or services. For example, Lancaster (1966) suggested that consumer buying decisions are not made on the basis of product utility, but according to perceptions of the social functions of goods. In other words, people do not purchase automobiles, they purchase personal mobility along with social status (Swann 2004). This distinction is not academic. As many producers of high-tech products and services are now finding, there appear to be definite limits to the ability of new technology to maintain symmetry with social functions. Accordingly, in the innovation society framework, the motivation behind innovation would not be expressed simply as demand for products, but rather for change in how individuals or social groupings live in the world – i.e. in *how* as well as what they produce and consume.

This perception is quite consistent with Schumpeter's definition of innovation which was simply *"doing things differently in economic life"* (Schumpeter 1939), a definition entirely consistent with his earlier identification of five basic categories in which innovation can occur (Schumpeter 1912):

- products,
- production methods
- sources of materials
- market structures
- new markets.

Crucially, although innovation in any of these categories may include technological change (i.e. new capital investment), Schumpeter claimed no necessary and certainly no exclusive relationship between innovation and (particularly 'new') technology. Even where technology or materials were involved, their novelty was not the key factor. To innovate, it was enough to deploy existing technology in new contexts or simply to identify a new source of materials or to market goods and services in different ways.

Many have argued that Schumpeter's list is narrow and that his categories are historically circumscribed. We agree. The important lesson in our view lies not the categories themselves, but in the extraordinarily complex, interactive, nuanced and *systemic* innovation dynamics that, together, they illustrate. Moreover, narrow as Schumpeter's list may be, on the indicator front we have not progressed very far beyond mapping and measuring the production of new goods and services.

Relating all of this to the innovation society framework, most striking overall (and lost in much subsequent innovation theory) is the extraordinarily high importance Schumpeter placed upon markets. Schumpeterian innovation revolves around the entrepreneurial function of anticipating, creating and organizing markets, whether the goods and services involved were technological or non-technological, existing or new.

Quite clearly, in Schumpeter's world-view, innovation was first and foremost an aggressive process, not just of following markets (looking for an opportunity to improve products and cut costs), but of *making* markets (re-defining problems and proposing fundamentally different solutions). As Henry Ford is said to have quipped – "*If I had listened to my customers, all they really wanted was a faster horse*". Like Ford, Schumpeter's typical entrepreneur was less an engineer or inventor and more a production manager and market maker – a Jobs rather than a Wosniak.

Regularly, scholars have noted the requirement for complementary actions and assets, particularly regarding the need to coordinate technology with the environments in which it will be implemented (Nelson & Winter 1982; von Hippel 1988; Cowan *et al* 1997; Roehrich 2004). However, technology is almost always identified as the primary driver of this coordination process, or as the central input around which the innovation process as a whole revolves.

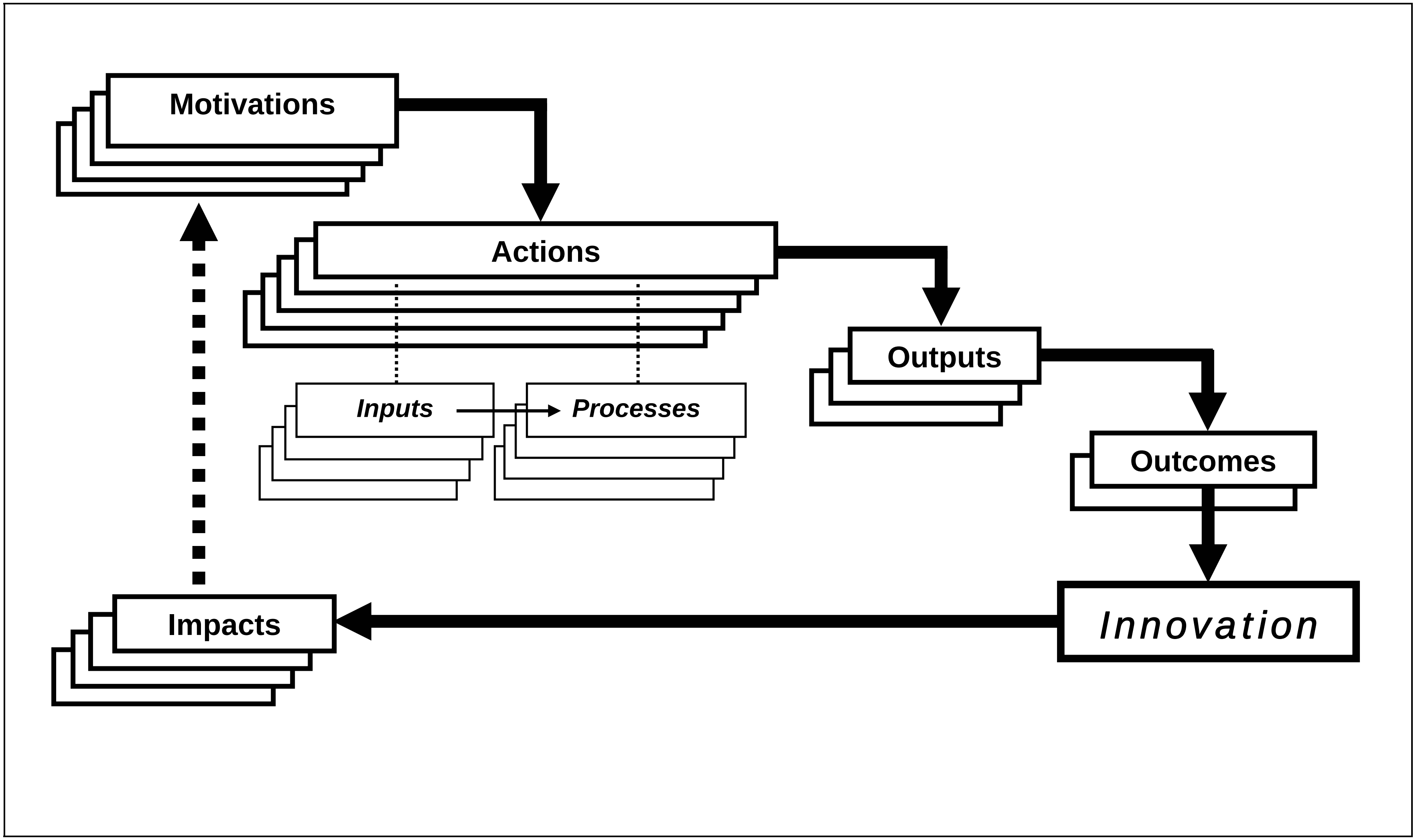
But in truth the question of which inputs constitute the cart or the pony is entirely open. For example, new value producing configurations, business models or financial instruments can be the definitive factors in establishing the commercial viability of a new technology – i.e. making it possible for a technology to become part of an innovation (Stabell & Fjeldstad 1998; Afuah & Tucci 2001; Chesbrough & Rosenbloom 2002; Chesbrough 2003; Hawkins 2003; Tassey 2004). Thus, for example Mandel (2000) argues that the technological developments in Silicon Valley during the 1990s would have been impossible but for innovations in the legal and financial instruments that permitted unprecedented access to venture capital. For him, the so-called 'new economy' is more about access to investment capital than about access to computer technologies and the Internet.

III. The problem of indicators for university-industry knowledge transfer

To the extent that for many industries and firms innovation often is often is tied closely to the development and/or application of technology, studies using the current regimes of indicators have succeeded in improving our understanding of innovation in the specific context of the production of goods and services. But when applied to assessing the broader dimensions of innovation and particularly the role of public institutions other than firms in the innovation system – in this case, universities – some fundamental questions about the entire indicator regime are chiseled into sharp relief.

Figure 1 illustrates a hypothetical 'sequence' for the innovation process that employs commonly used descriptive categories, but in a configuration that is consistent with the innovation society framework as just outlined. Although we refer to phenomena in Figure 1 as a sequence, we recognize that feedbacks are likely at various stages and that the process can be diverted, halted, abandoned or restarted accordingly.

Figure 1 - The Innovation Society



We assume that innovations are instigated by likely multiple and not necessarily coordinated demand factors or ***motivations***. Each of these can yield various ***actions*** which typically involve making ***inputs*** of time, money, knowledge, materials, human resources and so forth into various ***processes***, for example research, development, production or distribution. The result of each action is an ***output*** or outputs, which can emerge in the abstract form of new knowledge (whether codified or tacit) or in more concrete form as an invention. Outputs can remain outputs – i.e. never exploited. Or they can yield ***outcomes*** in the form of various applied endeavors and enterprises. The result of such outcomes can be ***innovation***, which we have defined specifically in the innovation society context as an observable change in the patterns, behaviors and practices of human life.

In our framework, ***impacts*** are distinguished from outcomes. Most impact assessment specialists stress that impacts are external and 'additional' to any given phenomenon (Buiserat *et al*, 1999; Kostoff, 1995). In other words, impacts are effects on some aspect of the socio-economic system that can be attributed directly to specific causes. To demonstrate a true impact, it must be demonstrated empirically that a given effect would not have occurred (or occurred to the same extent) but for the phenomenon in question. To finish off Figure 1, we speculate that impacts from specific innovations will in some way influence motivations for stimulating further innovative activities.

Comparing Figure 1 to our current base of innovation indicators, it is clear that current indicators focus almost entirely upon *inputs, outputs, outcomes and impacts*, and that by far we have focused mostly on inputs and outputs. Problematically, often these categories are confused with one another. In particular, impacts and outcomes are often conflated, thus leaving a huge analytical gap between the immediate and concrete consequences of outputs and the longer-term additional effects of innovations upon a broader range of socio-economic phenomena.

We prefer to make a simple distinction. Thus, if a patent is an output, then an exercised license in a spin-off firm is an outcome. Similarly, a published research report is an output and its use as the basis of a new standard method of analysis is an outcome. Economic impacts would include demonstrable changes in standard macroeconomic indicators. Non-economic impacts would include fundamental changes in perception or practice; for example, the re-conceptualization of our place in the world that is associated with the Darwinian revolution.

Inputs, outputs, outcomes and impacts constitute only one indicator axis – namely, 'what we measure'. The other axis concerns the relationship of the data to the phenomena being measured. On this axis, indicators can be distinguished as *measures*, *surrogates*, or *correlates*. Measures should be the direct quantification of phenomena. For example, counts of firms with origins in the university measure the extent of spin-off firm formation. Surrogates should be indirect representations of phenomena linked by explicit hypotheses; e.g. the expenditure of research dollars indicating research effort. Correlates are quantities linked to a phenomenon by a statistical hypothesis. For example, the level of employment of highly qualified personnel may be a correlate of innovative activity. These distinctions are critical to understanding the policy implications of indicators. Adapting Jaffe (1998), Table 1 presents a two-dimensional indicator matrix.

Table 1
Classification of indicators with examples (modified from Jaffe, 1998)

Concepts	Proxies	Correlates
Inputs		
Effort (person or equipment years)	Expenditures (e.g. HERD)	
Outputs		
Discoveries	Papers	Prizes
	Citations	
	Expert evaluations	
Inventions	Patents(?)	Patents(?)
Human capital	Degrees	Higher education expenditures
Outcomes		
New devices	Patents,	Licenses
New drugs	New drug applications	
Impacts		
Economic growth	GDP	GERD, BERD, HERD
Productivity growth	Productivity metrics	
Environmental improvement		Emission levels
Public appreciation		Science in newspapers

Turning to the indicators currently used most prominently to characterize university research, we encounter mainly examples of input and output indicators along with a few indicators intended to measure outcomes. How these relate to the multi-dimensional phenomena of innovation that are projected onto two-dimensions in Figure 1, can be analyzed with reference to the modified Jaffe scheme (Table 1). This is illustrated by the following selected examples:

Inputs

A major focus of analysis of university research is expenditure tracking. The HERD GERD and BERD surrogates are tracked for international comparison, and over time as an indication of government attitudes to university research. National league tables and time series play a central role in policy debates. HERD components are broken down (e.g. OECD, 2006, NSF, 2006) by sources (e.g. government, industry, institutional, other). Expenditures may be classified as basic vs applied research or science and engineering (S&E) vs other fields (NSF, 2006). The components are linked frequently by hypotheses (sometimes implicit) to function as correlates of outputs and/or outcomes (*vide infra)*.

The other major input is human resources. University faculty data are extensive (e.g. NCES, 2006) and graduate student and postdoctoral fellow data are available. For example US S&E populations are extensively characterized (NSF, 2006). Again, the S&E fraction may be hypothesized to correlate with certain outputs and/or outcomes. Data are available on university facilities expenditures and overall spending on higher education is an input - perhaps serving as a broad correlate of the generation of knowledge.

Outputs

The classic academic output measure is the number of publications. Sociology of science reminds us that a publication is not part of science until it is assimilated. Thus, citation has overtaken simple counts as a key output measure.

Disclosures and patents are commonly used as output measures with reference to product and process innovation. Indicators commonly are complied from reports of university technology transfer agencies (Arundel and Bordoy, 2006), but significant case studies indicate that equal or larger numbers of patent applications involving university inventors are filed through other channels (Meyer, 2000, 2003; Langford *et al*, 2006). One initiative links university output to patents by studying citation of university publications by industry patents as a surrogate for knowledge transfer. Unhappily, as anyone who has filed a patent application knows, patent agents and examiners as often identify the citations after the fact as the inventors do in the invention process, reducing this indicator to a correlate.

Human resources (graduate students, post doctoral fellows) are an input into the research process, but arguably more important to the innovation process as an output. Corporate research managers commonly identify highly qualified personnel as the most important university output overall

(Lazaridis, 2005, Salter *et al*, 2002) Most universities keep at least partial data for where their alumni find employment, but we have less information from the employer side as to what the skills composition of various parts of the innovation process might be.

Outcomes

The formation of spin-off companies involving university faculty researchers is an outcome that can be measured directly. Counts are found in AUTM and ASTP reports (AUTM, 2005; Arundel and Bordoy, 2006). A related outcome that is directly quantified is revenue from licenses and the equity earnings of universities. Often these two are nominated, (with total exercised licenses), as surrogates for commercialization. However, implicit in this relationship is the highly linear and largely discredited hypothesis that discovery leads to invention which in turn leads to spin-off commercialization activity. There is evidence, however, that this simplification may drive policy goals in directions toward distinctly sub-optimal impacts (Langford *et al*, 2006).

The complexity of outcomes has been recognized in many reports directed to policy communities. These include the paper by Martin and Salter (1996) for HM Treasury (UK), the report of Reamer *et al* (2003) for the US Department of Commerce, the Lambert (2003) review of university-business collaboration for the UK Government, the review of third stream activities for the Russell Group of Universities by Molas-Gallart *et al* (2002), the report on university research and knowledge transfer by the Association of Universities and Colleges of Canada (2005), and the study of public-private research collaboration by the Conference Board of Canada (Munn-Venn, 2006). These reports and reviews demonstrate a rough consensus about the pathways along which outcomes emerge from university research.

The seven-part outcome categorization adopted by Salter *et al* (2000) is representative and suitably subtle:

1. *Increasing the stock of useful knowledge.*
2. *Training skilled graduates.*
3. *Creating new scientific instruments and methodologies.*
4. *Forming networks and stimulating interaction.*
5. *Increasing capacity for scientific and technical problem solving.*
6. *Creating new firms [and licensing patents].*
7. *Social Knowledge.*

With this scheme, the problem becomes one of identifying a balanced set of indicators for all of the pathways along which outcomes, technological or not, emerge. Clearly the attention that input and output indicators now receive is a consequence of the hypothesis (not always explicit) that they are correlates of the growth of knowledge stocks, the training of research graduates, and increasing capacity for problem solving. In the next sections, we argue that immediate indicator development should be aimed at understanding both the mechanisms associated with the above pathways and how specific knowledge streams follow these pathways into the innovation process.

IV. Towards a new model of university-industry knowledge transfer

At present we measure inputs into university laboratories almost exclusively in terms of levels of public and private investment in basic research. In Canada, for example, the HERD is dominated by the amount of public research funding allocated to the natural and applied sciences**.** Increasingly we also monitor outputs, but almost entirely in terms of production-oriented indicators (patents, publications or prototypes). Furthermore, we tend to define the end-point of university involvement in the innovation process in terms of the commercialization of specific laboratory outputs (which usually represent only a tiny fraction of total laboratory output) often as related to the creation of spin-off companies. But even here, we measure only the quantity of spin-offs and commercial applications.

Our contention is that not only do these indicators fail to encompass an appropriate range of knowledge that we know already to transfer from the university into the innovation process, but that by focusing to narrowly upon the natural sciences and engineering they have created an artificial barrier to understanding the actual scope and significance of this process.

Landry *et al* (2001) have shown that university research outputs in (at least selected) areas of social science transfer to the marketplace also, and that as far as the actual transmission of knowledge is concerned, they often appear to transfer somewhat more efficiently than do natural science and engineering outputs,[4] Moreover, Hearn *et al* (2004) show how in today's service-rich economy, university research outputs in fine and applied arts can be transferred to the market as high-value commercial products and services as surely and in similar ways to outputs from engineering labs. Indeed, the size of markets for many such 'cultural' goods exceeds those of commonly identified high-tech industries.[5] Furthermore, Audretsch *et al* (2004) indicate that not only do

[4] To be clear, Landry *et al* (2001) focus on six social science fields, two of which (Social Work and Industrial Relations) are oriented to practical application. Political Science and Economics represent commonly required skills in administrative, policy and managerial contexts. Sociology and Anthropology are core sciences in management and market research.

[5] For example, in the US in 2002 (the last year of available Business Census data), the motion picture industry had receipts substantially larger than those of the computer hardware industry.

university-industry transfers emanate from a broad range of disciplines, but that different knowledge transfer dynamics can be observed for different knowledge sources within the university – transfers from social science being more likely to require physical proximity to specific industry sites than do transfers from natural sciences and engineering.

Focusing in on knowledge pathways

An easily implementable first stage in characterizing this wide variety of possible knowledge transfers and outcomes according to the various pathways as suggested by Salter *et al* is simply to assess and propose targeted additions to existing qualitative and quantitative research regimes that already pertain to these pathways. Several studies have begun already to address the indicator problem from this perspective (e.g. Molas-Galart *et al* 2002). We will illustrate the relevance of these pathways with data and observations drawn from case studies that we assembled concerning the knowledge transfer patterns within our own university.

Detailed information was drawn from three sources. First, the university provided a statistical analysis of faculty annual reports that deal comprehensively with three responsibilities: teaching, research, and service. Reports covered ~100 % of 1300 full time staff. Second, 219 faculty members responded to a questionnaire. Third, a number of respondents agreed to be interviewed regarding their individual knowledge transfer experience.

The first lesson from the faculty annual reports is the large and varied extent of engagement with the community. Instances of consulting to firms (the majority), governments and organizations exceed 500. The large faculty of Medicine reported 220 such assignments, engineering 73, and environmental design 67. Under community service a wide variety of organizations, and government agencies across the country appear as sites of engagement. Lowest intensities are from faculties of business and medicine at 0.46 and 0.59 reports per faculty member. Representative high per faculty member values are Fine Arts at 1.32, Kinesiology at 1.53, and Environmental Design (architecture, industrial design, planning) at 1.68. Engineering and science are intermediate at 0.7. Eleven faculties reported software development. The leading developer was Science [with 28] followed by Engineering [23] and Environmental Design and Medicine [both with 8]. Clearly, multiple channels of communication exist. A second lesson is that IP protection activity is substantial but focused in the faculties of Engineering, Medicine and Science. Total reports of patents, copyright filings, and registered industrial designs number 101 with 0.26 per faculty member in Engineering, 0.14 per member in Science, and 0.09 per member in Medicine. These numbers contrast with about 30 patent applications per year by the university's technology transfer agency where patents issued run at about 15 per year.

The faculty survey asked first what is perceived to be the best way to achieve social benefit from research. Publication in the open literature was chosen by 144 respondents, collaboration with users by 100, and launching a venture or business by 19. (Individuals could choose more than one response.) However, 39 indicated that they had started a business or another venture creating employment and/or revenue, and another 15 expressed an intention to do so. Leading faculties were medicine, engineering, science, and social science. The survey allowed a probe of the outcomes of consulting and collaborative activity. The identified benefits to partners included new product or services (23%), improvement to a product or service (22%), administrative systems, new or improved (15%), market entry or expansion (26%). This is clearly not exclusively technology focused.

Our semi-structured interviews offered further insights into the variety of processes involved and highlighted the limitations imposed by the complexity of the knowledge transfer relationship upon the significance of statistical summaries (of the annual reports and the survey responses). Table 2 shows several prominent examples from these interviews of actual knowledge flows that correspond to each of the pathways identified by Salter *et al*.

Table 2.
Qualitative identification of knowledge flow pathways

Knowledge pathway	Type of example identified in interviews
Forming networks and stimulating interaction	• major research consortia • direct participation in a large scale industry projects
Creating new firms and licensing patents	• successful licensing to an established firm • spin-off involving a university scientist
Creating new scientific instruments and methodologies	• services from a unique university research facility • development of a new diagnostic protocol.
Increasing capacity for scientific and technical problem solving *Increasing the stock of useful knowledge*	• consulting o contributing to the development of effective project management practices o working in a regional R&D cluster
Training skilled graduates	• relevant in every interview • recruiting research associates internationally who remain in a local cluster
Social Knowledge	• social factors in project contract construction

Finally, it is intriguing also to consider the 'ladder of knowledge utilization' concept introduced by Landry *et al* (2001). As shown in Table 3, this provides a process view that relates knowledge use to decision-making processes using a scale of knowledge utilization with six cumulative stages in rising order.

Table 3
Stages in the ladder of knowledge utilization
(adapted from Landry et al 2001)

***Stage One:* transmission**	user obtains knowledge
***Stage Two:* cognition**	user absorbs knowledge
***Stage Three:* reference**	user cites and elaborates knowledge
***Stage Four:* effort**	user deploys knowledge
***Stage Five:* influence**	knowledge is used in decision-making
***Stage Six:* application**	knowledge is applied directly to products, services, processes etc.

Landry *et al* apply this ladder model to empirical analysis of large samples of Canadian social scientists, natural scientists and engineers and their overall observations are highly relevant to indicator construction. As the complexity of the relationship between university researchers and industry increases so usually does the rate at which the knowledge ladder is ascended. Basic research projects tend to have relevance mainly at the lower end of the ladder whereas more collaborative and applied projects tend to populate the upper end.

Some immediately possible first steps

A recent report on measuring socio-economic impacts of academic research in the UK (Molas-Gallart *et al*, 2002) offers a large number of possible metrics with warnings about difficulties, costs, and needs for further research. It is notable, however, that a majority still focus on the single pathway of licensing and spin-offs. However, even by using already accessible (or nearly accessible) data and more-or-less standard methods, several immediate steps could be taken to improve outcome indicators in the other six outcome categories.

Step One – Normalize cost input indicators:

Financial input data (e.g. HERD) is widely available and used frequently. But as they are at least implicitly recognized as a correlate of all of the outcomes, their analysis should be balanced to recognize the importance of different costs of knowledge. For example, input data indicate generally that the costs of medical research exceed those of science and engineering research, which in turn exceed the costs in all other fields. Input data should be normalized for the scale of research expenditure in each of the contributing disciplines and knowledge streams.

Step Two – Match graduate knowledge with innovation roles:

There is reasonable consensus that knowledge transfer by graduates is the most significant pathway for the influence of university research (Salter *et al* 2000; Munn-Venn, 2006). But universities impart a wide variety of knowledge inputs, some of which is attitudinal and tacit (Nelson 1987; Senker 1995). This poses a challenge for indicator development. A tantalizing hint of what is possible can be detected in the Canadian National Graduates Survey (which has analogues in many countries). Presently, the survey provides information about the educational requirements for various jobs. But it does not link job descriptions, educational requirements and knowledge fields with a model of the innovation process. At a more concrete numerical level, there is considerable information on relative wage patterns among young highly educated workers (see, e.g., Morissett,*et al*, 2005). On the hypothesis that wage patterns in knowledge intensive sectors are correlated to creative contributions, such data might be examined to identify possible decompositions tracking the role of graduate knowledge in innovation.

Step Three – Valorize new instruments and methodologies:

Development of new instrumentation and methodologies is a key output of university research (Rosenberg 1992) and Von Hippel (1998) notes the close parallel between research instrumentation and methodologies and those adopted by firms. Salter *et al* (2000) suggest this as the second most important contribution of university research to economic activity. There has been considerable interest in indicators derived from firm investments in capital equipment, but we might also track the origins of this equipment in university research.

Step Four – Build partnership indicators:

It has been a mistake to group all industry funding and all government funding into separate envelopes. Our observations within our own university suggest the hypothesis that all of the knowledge pathways are supported by active interaction with users. If we apply the Landry model to funding sources, then research funding associated with user sponsorship and participation is likely to correlate to outcomes. Key examples of this type of funding are research consortia that include users, industry sponsored research chairs and research contract work in laboratories that have continuing contract research relationships with users. It likely is not difficult to segregate data on these types of research sponsorship. Thus, we propose an input metric for funding modalities where industry and University researchers are involved in longer-term relationships. In this case, industry funding should be summed with the relevant granting agency contributions to give an overall indicator of research funding for *partnership* activity.

*Step Five – Expand university faculty surveys**:***

In universities that use systematic annual reporting systems, statistical summaries of activities in various categories can provide insight into levels of activity at various stages of the Landry *et al* ladder. An effort should be made to define standardized reporting categories such that these outcomes can be clarified. If annual reports cannot be accessed widely, a new survey project on a national basis could present these questions to a sample of university faculty. Such a survey would be a valuable complement to existing firm-level innovation surveys and at least two significant new indicators could result:

- Participation in user seminars and conferences as a surrogate for the outcomes of increasing problem solving capacity and network building.

- Publication and presentation in user oriented media, including trade journals and general media, as a correlate for increasing the stock of useful knowledge at the third Landry *et al* stage or higher.

A faculty survey instrument might deliver many kinds of additional information. Analysis of currently available annual report data makes it clear that a better understanding of faculty IP activity is possible than that derived from reports of technology transfer offices, and that a more nuanced understanding of consulting activity might be achieved. Since IP activity not reported through technology transfer offices frequently reflects projects done in partnership with users, it may be a significant indicator of more diverse and complex relationships. A clearer understanding of consulting activity might allow differentiation of the role played by this important but under-documented activity in several of the knowledge flow pathways.

Step Six – Develop social knowledge indicators:

The fundamental hypothesis motivating this paper is that innovation must be perceived as a holistic social process involving the combination of many more knowledge dimensions that normally encompassed by technology. University research and training encompasses the full gamut of human knowledge university research belongs on the pathway labeled “social knowledge”. Appropriate indicators will need to come from revised innovation surveys that are appropriate to a broader range of industries. As well, they surveys of manpower and graduates will need to probe changing roles of highly qualified personnel.

V. Conclusion

Our innovation society heuristic was developed in order to revitalize the original emphasis of Schumpeter and others upon the systemic societal dynamics of innovation. In the indicator development context, we see it as a way to argue for a broader definition and more nuanced calculus of knowledge production and transfer in the innovation process.

In this paper we have shown that the basis for expanding our calculus already exists and could be implemented relatively quickly provided that we re-frame innovation conceptually as stemming from the outcomes of various forms of knowledge application and not just from financial and technological inputs and outputs as related to industrial firms. Instead, we must consider the broader societal dimensions of knowledge production, transfer, application and evaluation and particularly the role of knowledge as produced in disciplines other than the natural and applied sciences. The university occupies a crucial position in this structure and we must learn to characterize more of its knowledge outputs statistically if we are to assess its true role in the innovation process.

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