Part Three

INNOVATION: CAN SOMETHING NEW BE MEASURED?

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Chapter 4

INNOVATION SURVEY INDICATORS: WHAT IMPACT ON INNOVATION POLICY?

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4.1. Introduction

The first Blue Sky conference in Paris in 1996 introduced a wide audience to some of the results of the first Community Innovation Survey (CIS) from 1993, which was arguably one of the most comprehensive major sources of new innovation data at the time. The purpose of the CIS and other innovation surveys based on the first edition of the *Oslo Manual* was to overcome some of the limitations of the research and development (R&D) surveys. Two main goals were to provide data on innovative activities that were not based on R&D and to provide output measures of innovation.

The CIS is now implemented every two years in all member states of the European Union (EU). The results of the fourth CIS, covering innovation activities between 2002 and 2004, became available in 2006 and 2007. The fifth CIS was in the field in early 2007 and planning for the sixth CIS, which will implement the recommendations of the third edition of the *Oslo Manual* (OECD/Eurostat 2005), is underway.

With results from up to four consecutive surveys, one would think that the CIS would play an essential role in assessing and developing innovation policy. Unfortunately, this has not happened to the extent anticipated in 1996. European policy largely relies on long-established indicators for R&D. These indicators are excellent measures of formal, creative activities to develop innovations in-house, particularly in manufacturing. However, the CIS collects data on four characteristics of innovation in modern knowledge economies that are not adequately covered by R&D indicators: the diffusion of technology, the role of 'distributed knowledge bases' in sharing information of value to innovation (Smith 2002, 2004), the continual increase in the economic importance of the service sector, and the importance to many

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firms, in both the manufacturing and service sectors, of informal innovative activities that are not based on R&D.[1]

This chapter examines why R&D indicators still dominate innovation policy making in Europe and makes several suggestions for improving the usefulness of the CIS. This requires returning to some of the original goals of the CIS and using the CIS to construct new indicators that better meet the needs of the policy community.[2] Several examples of new indicators are provided, including an output measure with better international comparability, an indicator for knowledge diffusion, and a set of indicators for firms' innovative capabilities.

4.2. The policy context for innovation indicators

Between 2004 and 2006, the author and colleagues at UNU-MERIT[3] interviewed 67 members of the policy community – 55 from 15 European countries and 12 from Canada, Japan, Australia and New Zealand – on their use of and need for innovation indicators. R&D indicators were the most widely used and were considered to be the most valuable. In contrast, only a minority of respondents referred to the use of indicators drawn from the CIS or similar innovation surveys in policy making or evaluation.

Within the EU, there are two main reasons why the policy community strongly emphasizes R&D indicators over innovation survey indicators. The first is due to the continuing power of the linear model of innovation, while the second is due to the structure of innovation support programmes.

4.2.1. The case for R&D indicators

A major factor in the continuing popularity of R&D indicators is the key role that R&D plays as the source of inventions in the science-push or linear model of innovation. The countless announcements of the death of this model and its presumed replacement with "systemic" models using Schumpeterian definitions of innovation are decidedly premature. The continuing influence

1. Bell (2006), using data from the SESTAT survey for the United States, estimates that two-thirds of scientists and engineers in the private sector are not employed as researchers. Many of them could be involved in informal activities to develop or implement innovations.

2. Godin (2002) comments that the innovation surveys "ended up measuring innovation the way they measured R&D, *i.e.* in terms of inputs and activities," rather than fulfilling their original goal of measuring outputs. The view of this author is that the design of the CIS questionnaire is compatible with the original goal. The problem is in how the data are used.

3. United Nations University – Maastricht Economic and social Research and training centre on Innovation and Technology.

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of the science-push model has arguably hindered policy interest in a wider range of CIS indicators.

Academic research using CIS data has not managed to overcome the policy focus on the science-push model of innovation because most academic research has also focused on R&D. A UNU-MERIT analysis of 176 academic papers in English using CIS data found that only 5% explored innovation strategies, performance, or other characteristics of innovative firms that did not perform R&D, although many of them look at knowledge sharing from a systemic perspective.[4] In addition, academic research based on the CIS has not been widely used by the European policy community. The UNU-MERIT interviews found that policy analysts rarely use this body of research because academic papers are not focused on their needs. Out of the 176 academic papers using CIS data, only 21 (12%) were found to make any policy recommendations. Most of these 21 papers included only a few sentences or a single paragraph that discussed the policy relevance of the results. One of the problems, as pointed out by Veugelers and Cassiman (2005), is that CIS results for one country do not provide a strong basis for policy development. Policy-relevant results need to be replicated across several countries, but this is difficult due to data access restrictions that usually limit access to CIS data to one country.

The second reason for the policy focus on R&D indicators is due to the dominance of supply-side R&D support programmes in innovation policy. An example is the Lisbon Agenda, and specifically the Barcelona European Council's initiative to solve the EU's decline in competitiveness with a proposal to increase European R&D intensity to 3% of gross domestic product (GDP) by 2010. This fixation on R&D has probably delayed the slow progress made over the 1990s towards an expanded view of innovation that includes informal activities[5].

The dominance of R&D support programmes in documents and political discussion also reflects the distribution of public funds for different types of innovation policies. Although there are no official statistics on the amount of funding for R&D versus other types of innovative activities, some relevant data are available on the Trend Chart website, which maintains an extensive database of innovation programs in each of the EU member states. A thorough search of the database in September 2006 identified 54 programs that did not necessarily involve R&D. These largely consisted of programs to fund the

4. The UNU-MERIT database is maintained by Dr. Cati Bordoy and includes all papers, in English, presenting microeconomic analyses of data from CIS1 through CIS4. The database was last updated in January 2007.

5. An example is the influential 2005 *Green Paper on Innovation*, which noted the importance of including innovation activities other than R&D (CEC 2005).

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diffusion of technology and skills, particularly to small and medium-sized enterprises (SMEs).[6] It is unlikely that this covered all non-R&D innovation programs, but it should have captured the range of programs on offer. Annual expenditure in euros was available for 85% of the 54 programs, which covered the following areas:

- Training staff from SMEs, particularly in technology requirements and innovation management;
- Technology adoption subsidies, particularly for modernization;
- Subsidies to acquire licences to new technology;
- Subsidies to hire skilled science and engineering (S&E) staff; and
- Manufacturing extension services to help identify firms' needs for new technology.[7]

These five policies are likely to be most relevant for SMEs that do not perform R&D or which have low innovative capabilities. On average, the 10 states that joined the EU in 2004, plus Greece and Portugal, spend eight times more on a per capita basis on these types of programs than the more developed EU member states, but overall these programs account for less than 2% of EU public expenditures on R&D. Even allowing for substantial under-reporting in the Trend Chart database, programs to support innovative activities that do not involve R&D probably account for less than 5% of all government support for innovation.

The low public investment in these types of programs suggests that indicators for innovation activities that are not based on R&D, such as the diffusion of technology and skills, will never be as important to the policy community as R&D indicators, with the possible exception of the 10 member states mentioned above. However, such policies could be relatively more important to SMEs (a target of many policy actions) than the low investment would suggest. An Innobarometer survey in 2004 asked a sample of 4 534 innovative SMEs, covering all 25 EU member states at the time, if any of eight types of innovation support programs were "crucial to any of your innovation projects, such that the innovation would not have been developed without the support." Almost a third (31.5%) of respondent SMEs that used two or more innovation support programs cited support for collaboration as

6. See *http://trendchart.cordis.lu/*

7. Most EU countries support a system of regionally based technology transfer or innovation offices to provide support and technical advice, such as the Manufacturing Advisory Service (MAS) in the United Kingdom or OSEO-ANVAR in France. They provide general education programs, including demonstration projects, visits to successful innovative firms, help with identifying relevant new technology and courses on innovation management.

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crucial, followed by programs to support research (cited by 25%) and the adoption of process technology (cited by 14%) (Arundel 2004). The latter is supported by several of the five types of programs listed above, while the first and fourth programs can be relevant to collaboration by improving a firm's innovative capabilities.

Increased interest in the role of demand in innovation could also lead to greater interest in diffusion indicators. Both the influential Aho Report (CEC 2006) and the Competitiveness and Innovation Framework Program (CIP) (CEC 2005) stress markets and demand, including the role of lead users, and discuss the need to increase the rate of adoption within Europe of information technology in the service sector. The CIP proposal observes that "making innovation work means innovation capacity building, the uptake of new technologies and of existing technologies in a new context and carrying them through to the business level." To achieve these goals, the CIP proposes an entrepreneurship and innovation program to support the transfer of technology, the uptake of technologies and applications, and co-operation between universities and firms. Two other sections of the CIP proposal support the adoption of information and communication technology (ICT) and the creation of markets for sustainable production methods and energy-efficient technology.

The Aho Report and the CIP proposal are hopefully part of a gradual shift in Europe from supply-side support for the creation of new ideas through R&D to a concerted effort to ensure that these ideas also find their way to firms that can apply them to their new products, processes and services. This shift was also reflected in the UNU-MERIT interviews. The interviewees were asked an open-ended question about the types of new indicators that they would like to have. The most frequent request was for indicators for the process of commercialization and collaborative activities involving innovation. The latter was of the greatest policy interest, cited by interviewees from all but two of the 19 countries.

4.3. Improving the relevance of the CIS

An analysis of the interviews, program funding, and several major innovation policy documents indicates that R&D activities will remain the core focus of innovation support programs in Europe. Nevertheless, the policy community is interested in better indicators for activities such as commercialization and collaboration, which will involve both R&D performing firms and firms that use other methods to innovate. As recognized by the Aho Report and the CIP proposal, European competitiveness will depend on both R&D *and* on the diffusion and application of new technology (which may or may not involve R&D).

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The CIS and similar innovation surveys can provide useful indicators for both sets of policy needs, but this will require the development of new indicators, in addition to the indicators that are currently publicly available, for instance on Eurostat's New Cronos Web site or in the Eurostat publication *Innovation in Europe* (EC 2005). The existing set of indicators is not adequate because the indicators either lack sufficient detail to meet policy requirements or they do not provide the type of information required by policy. For instance, very few indicators are provided separately for both R&D performing and non-R&D performing firms. This reduces the value of many indicators for developing innovation policy for both groups.

One solution is to develop complex indicators based on the responses to more than one survey question. Complex indicators can reveal much more about firms' innovation activities and strategies than simple indicators based on the frequency of responses to a single question.

This section gives examples of new complex indicators for new-to-market innovations, knowledge diffusion and innovative capabilities. All three examples were inspired by the interviews with the policy community and are based on an analysis of the micro-aggregated CIS3 data that were released by Eurostat in July 2006.[8] A major drawback is that the dataset contains results for only two highly developed countries, Belgium and Iceland, and for 10 less innovative EU member states – another illustration of the problem with access to CIS data. Nevertheless, the results demonstrate the possibilities of using the CIS to construct new indicators.

The new indicators described below use only non-interval-level data with high response rates to a specific question and are weighted to reflect the population of firms in each country. The three examples concern how firms innovate, but only the third example is directly linked to R&D. The relevance of the other two proposed indicators could be improved by providing separate results for both R&D and non-R&D performing firms.

4.3.1. New-to-market innovations

The published CIS indicators include an output indicator for the innovation sales share[9], defined as the percentage of total product sales, aggregated across all firms, from products that were "new to the firm's market." Using CIS3 data, the best-performing European countries for the innovation sales share were Spain with an innovation sales share of 16.3%, followed by Finland (14.5%) and Portugal (10.8%). In comparison, percentages

8. All results are weighted to reflect the population of firms in each country.

9. This indicator is included in DG Enterprise's European Innovation Scoreboard (see *www.proinno-europe.eu/doc/EIS2006_final.pdf*, last accessed April 22, 2007).

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were much lower for Germany (6.2%), France (5.8%), Belgium (5.1%), the Netherlands (3.1%) and the United Kingdom (1.7%).

These results are puzzling and tend to reduce confidence in the CIS. No one expects Portugal's performance on this indicator to be more than three times better than the Netherlands and more than five times better than the United Kingdom. The explanation is that the question asks about sales from products that were new to a *firm's* market. Portuguese and Spanish firms could have outperformed the Netherlands and the United Kingdom because they were introducing innovations, already available on other markets, to a less developed domestic market. Furthermore, a firm need not have developed the innovation in-house through R&D, but could simply have been passing on an innovation that had been developed by another firm based in a different market. Consequently the combination of results for R&D and non-R&D performing firms is misleading.

The problems with this indicator can be partially rectified by building a complex indicator that includes data from a CIS question on the firm's market: local, national or international.[10] A reasonable assumption is that firms that have introduced a new-to-market innovation *and* are active on international markets are subject to greater competition, and therefore new-to-market innovations will be more comparable among firms based in different countries. A second step, not explored here, is to provide separate indicators depending on how firms innovate (see section 4.3.2 below).

Table 4.1 presents results for three new-to-market innovation indicators. Column A, the publicly available indicator for the innovation sales share, shows that firms based in Spain, Portugal, Romania, the Czech Republic and Slovakia performed better than firms based in Belgium. Belgium's relative performance improves for the percentage of firms that introduced at least one new-to-market innovation (column B). Column C gives the results for a complex indicator: the percentage of firms that introduced any new-to-market innovations *and* were active on an international market.[11] In Belgium, 8.2% of firms meet these requirements, compared to only 1.2% of firms in Spain. Belgium is the leading country for this indicator, whereas Spain is the second worst performer after Bulgaria. These results suggest that Spain's high performance for the innovation sales share was from product sales on the domestic market that may already have been available

10. The question asks for the firm's main market. An international market can include a neighbouring country. Responses to the CIS4 questionnaire will provide more accurate results because it asked about local, national, other EU, and non-EU international markets.

11. Given full interval-level data, the indicator can be calculated as the share of total product sales from new-to-market innovations by firms active in international markets.

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on other markets. In general, the complex indicator in column C provides results that should be considerably more comparable across countries.

Table 4.1. New-to-market innovation indicators

		A	B	C	
		Innovation sales share	Any new-to-market innovation	Any new-to-market innovation *and* active on an international market	Ratio C/B
Belgium	BE	5.1	18.0	8.2	0.45
Bulgaria	BG	2.1	6.3	1.0	0.17
Czech Republic	CZ	7.2	12.3	7.4	0.61
Estonia	EE	4.5	13.9	4.7	0.34
Greece	GR	2.9	11.3	2.2	0.19
Iceland	IS	2.0	11.1	2.9	0.26
Latvia	LV	2.3	17.8	6.4	0.36
Lithuania	LT	4.3	13.1	2.7	0.21
Portugal	PT	10.8	19.8	4.4	0.22
Romania	RO	7.8	13.8	3.5	0.25
Slovakia	SK	6.2	8.0	3.4	0.43
Spain	ES	16.3	11.3	1.2	0.11

Source: CIS3 micro-aggregated data referring to innovation activities in 1998–2000.

4.3.2. Knowledge diffusion

Knowledge diffusion is an essential aspect of innovation by both R&D performing and non-R&D performing firms. It includes: the acquisition of knowledge that does not require interaction with the source,[12] such as the purchase of capital goods or services, including the licensing of intellectual property; the acquisition of knowledge that is freely available from sources such as scientific publications or through attendance at trade fairs; and the acquisition of tacit knowledge obtained directly from other people through collaboration. The third edition of the *Oslo Manual* (OECD/Eurostat 2005, 82) stresses the importance of collecting information on each of these three methods of knowledge diffusion.

12. A good indicator for the first kind of diffusion could be produced using expenditure data on the acquisition of machinery, equipment and software. The equivalent CIS3 data have not been used because of a high non-response rate to this question, but the response rate in CIS4 appears to have improved substantially.

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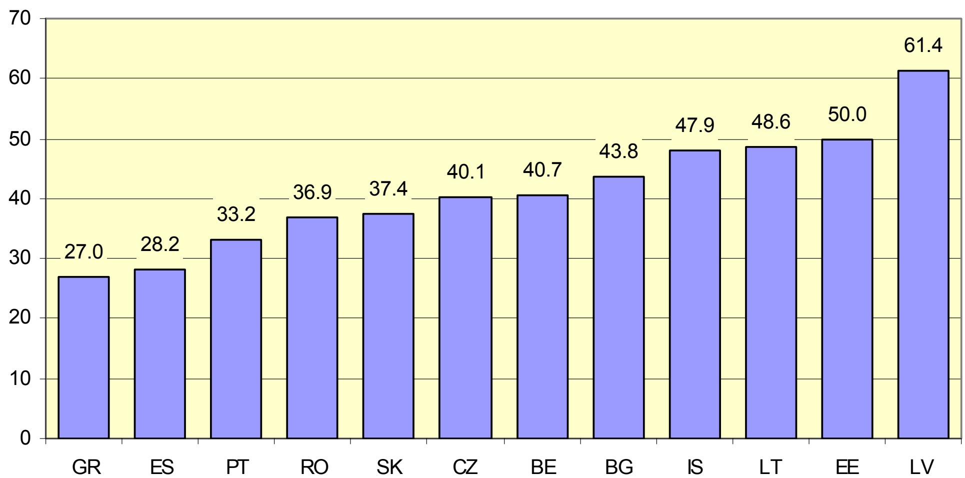
These three types of diffusion can be subdivided into two groups: active knowledge diffusion, in which firms develop innovations through interaction and collaboration with other firms or institutions; and non-interactive knowledge diffusion, in which firms obtain external knowledge only through open sources or through the purchase of technology.

The CIS3 can be used to identify active knowledge diffusion, defined here as a positive response to one or more of three questions: *a)* Were the firm's *product* innovations developed mainly in co-operation with other enterprises or institutions? *b)* Were the firm's *process* innovations developed mainly in co-operation with other enterprises or institutions? *c)* Did the firm have one or more co-operative arrangements on innovation with other enterprises or institutions? The results of the analysis are given in Figure 4.1.

Figure 4.1. Percentage of innovative firms developing innovations through collaboration (active knowledge diffusion)



Source: CIS3 micro-aggregated data referring to innovation activities in 1998–2000.

Other types of indicators for knowledge diffusion can also be constructed. For example, it is possible to combine knowledge diffusion through both technology adoption and active collaboration by including firms that gave a positive response to the question about the acquisition of advanced machinery and equipment, or that reported that their product and process innovations were developed mainly by other firms. Such an indicator can identify the importance to firms of all types of knowledge diffusion. For the 12 countries in the dataset, 78.7% of firms reported innovating through one or more

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diffusion-based methods, highlighting the crucial importance of knowledge diffusion to innovation.

4.3.3. Innovation modes

The *Oslo Manual* defines a firm as innovative if it has introduced at least one product or process that was new to the firm itself. This means that no distinction is made between firms that purchase new technology off the shelf with minimal effort and those that have extensive in-house R&D projects to develop innovations. Although this indicator is widely available, it is of limited value to policy because it combines firms with very different methods or modes of innovating. An increase or decrease in this indicator does not necessarily mean that innovation support policies have succeeded or failed: for example, a decrease in the share of firms with highly developed innovative capabilities combined with an increase in minimally innovative firms could produce a net increase.

The solution to this problem is to develop a set of indicators that describe *how* firms innovate, using a methodology that assigns all CIS respondents to one, and only one, category. Previous research has taken this approach (Tether 2001; Arundel and Hollanders 2005), but the relevance of the results was hampered by using categories that did not closely reflect policy needs or by using questions with high non-response rates, requiring complex and non-transparent statistical routines to assign all firms to the most appropriate innovation category.

The method proposed here and summarized in Figure 4.2 avoids the non-response problem by using only nominal-level questions and improves policy relevance by focusing on two innovation characteristics that, according to the UNU-MERIT interviews, are important to European policy: collaboration, and formal in-house innovation based on R&D (or proxied through patenting). The first axis for this indicator refers to whether or not a firm was involved in active knowledge diffusion through collaboration (defined in section 4.3.2). The second axis refers to whether or not the firm had formal in-house creative activities, measured by its response to one of two questions: *a)* Did the firm perform R&D? or *b)* Had the firm applied for at least one patent? Those that responded positively are defined as "inventive" firms that were most likely to produce innovations containing a major technical advance. Those that did not answer either question positively were informal innovators with the ability to develop innovations on an ad hoc basis, such as through production engineering. It should be noted that Figure 4.2, and the results given in Table 4.2 and Figure 4.3, exclude non-

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innovative firms, which account for a large share of all firms in several of the less innovative countries.[13]

Figure 4.2. Innovative firms' methods of innovation

	Non-collaborators	Collaborators
Informal innovation activities	**A.** Informal non-collaborators **41.4%** *(8.9% were technology adopters)*	**B.** Informal collaborators **15.8%**
Formal innovation activities	**C.** Formal non-collaborators **24.7%**	**D.** Formal collaborators **18.1%**

Source: CIS3 micro-aggregated data referring to innovation activities in 1998–2000.

Note: Percentages in bold sum to 100% of all innovative firms.

Cell A: Firms that only reported informal innovation activities in-house and had no innovation activities based on collaboration or co-operation with other firms or institutions.

Cell B: Firms that only reported informal innovation activities in-house, but collaborated or co-operated with other firms or institutions to develop innovations.

Cell C: Firms that reported formal innovation activities (performing R&D or applying for a patent), but had no innovation activities based on collaboration or co-operation with other firms or institutions.

Cell D: Firms that reported formal innovation activities (performing R&D or applying for a patent) and collaborated or co-operated with other firms or institutions to develop innovations.

The goal for policy is to increase innovative capabilities by shifting the national distribution of innovative firms towards quadrant D in Figure 2, and to encourage non-innovative firms, particularly in less innovative countries, to enter one of the four innovative categories. Of note, the group represented in quadrant A, which has the largest share of innovative firms, includes firms that only innovate through adopting technology developed by other firms or institutions (technology adopters).

Table 4.2 gives some characteristics of the four groups of innovative firms, with separate results for the technology adopters in quadrant A of Figure 2. Compared with the average, a significantly lower proportion of firms in quadrant A was active on international markets, had sourced external knowledge (although almost all innovative firms derived some knowledge for their innovation activities from external sources) and had introduced both a product and a process innovation. These results suggest that the informal non-collaborators had fewer intensive innovation activities than the

13. The share of non-innovators was 50% in Belgium, 88.4% in Bulgaria, 68.1% in the Czech Republic, 63.4% in Estonia, 71.9% in Greece, 46.7% in Iceland, 60.8% in Latvia, 71.8% in Lithuania, 54% in Portugal, 82.8% in Romania, 80.4% in Slovakia and 66.9% in Spain.

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other groups, but some of them could have had reasonably advanced innovative capabilities.

Table 4.2. Characteristics of innovative firms

	A-1 Informal non-collaborators	A-2 Technology adopters	B Informal collaborators	C Formal non-collaborators	D Formal collaborators
International market[1]	17.4%	9.5%	22.7%	25.5%	36.9%
Source external knowledge[2]	82.8%	82.5%	88.6%	89.2%	95.8%
Product innovator	66.0%	52.8%	64.1%	85.1%	85.9%
Product & process innovator	31.2%	10.9%	42.1%	43.3%	64.4%

Source: CIS3 micro-aggregated data referring to innovation activities in 1998–2000.

1. Firm's main market.

2. Gave a rating of "high" or "medium" importance to at least one of seven external knowledge sources for their innovation activities: suppliers, customers, competitors, universities, government research institutes, conferences/ meetings/journals and fairs/exhibitions.

Figure 4.3 shows that there are large differences by country in how firms innovate. For example, compared with Belgium, Spain and Greece had low percentages of innovative firms that collaborated on innovation, particularly firms that engaged in formal innovation activities. Almost all innovative firms in Bulgaria innovated through informal non-R&D-based activities, whereas this proportion was much lower in Belgium and Greece.

The information in this indicator on the distribution of firms' innovative capabilities should help policy analysts to acquire a better understanding of national innovative capabilities and to develop policies that can shift firms' capabilities towards greater collaboration and formal innovation activity. The indicator should also be directly relevant to the policy community because it identifies R&D and non-R&D performing firms and the incidence of collaboration in both groups. As shown in Table 4.2, both R&D performance and collaboration are associated with a higher incidence of activity on international markets, product innovation, and combined product and process innovation.

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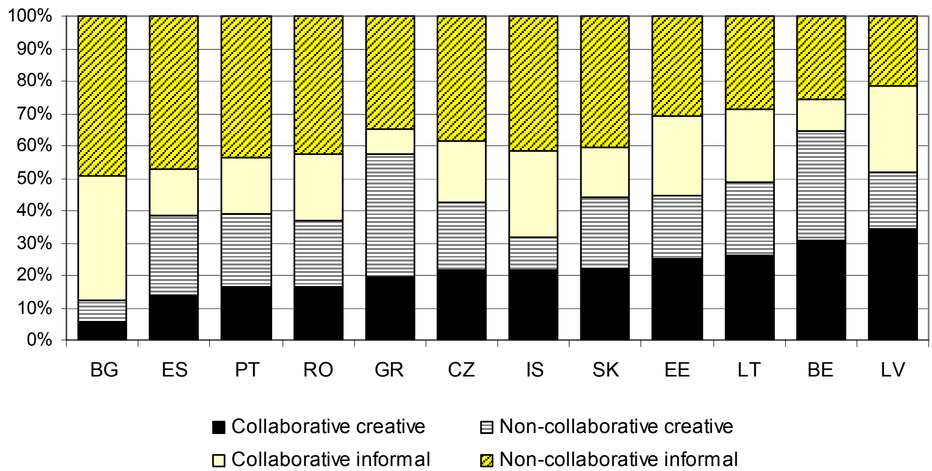
Figure 4.3. Innovative firms' methods of innovation, by country



Source: CIS3 micro-aggregated data referring to innovation activities in 1998–2000.

4.4. Conclusion

This chapter contends that one of the main barriers to the use of the CIS by the policy community is a lack of indicators and analyses that are relevant to policy needs. In part, this is unsurprising, because one of the main goals of the CIS is to provide data on non-R&D-based innovation activities, whereas supply-side R&D support programs dominate innovation policy. The growing policy interest in demand, commercialization and collaboration should enhance the value of the CIS, but this also requires using the CIS data to develop appropriate indicators on these issues. The academic community could also help by discussing the policy relevance of their research.

One of the main problems to date is poor links between the policy community and statistical offices and academics that use the CIS data. One respondent to the UNU-MERIT interviews noted that analysis "must be pull driven – pulled by policy interest and not the other way around. Without these interface mechanisms, the analytical results of the CIS are not visible." According to a second respondent, the results of the CIS are rarely used to inform policy because of the "long, long distance between the people who write papers based on the CIS and the decision-making level at ministries."

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The three examples of new types of indicators that could be created using CIS data are a response to suggestions made by the policy analysts interviewed by UNU-MERIT. However, this is an ad hoc and incomplete method of identifying the types of indicators that would be of use to the policy community. In this respect, Statistics Canada offers a good example of the right approach. The division responsible for the Canadian Survey of Innovation is frequently in contact with its users in government ministries and can provide customized analyses of data or implement additional surveys, based on funding by the ministry making the request. This process ensures that Statistics Canada has ongoing interaction with the users of innovation data and the in-house expertise to respond to their needs.

Fortunately, there are several initiatives underway to improve available indicators based on the CIS and to solve some of the problems with micro-economic analysis. The OECD, Eurostat and the group of Nordic countries are currently supporting research on the development of new CIS indicators. The OECD is also organizing a series of parallel econometric analyses of national innovation survey data in order to overcome limited access to data from more than one country. By the spring of 2007, over 15 countries were participating. This initiative should provide more robust results on major policy issues, such as the link between innovation and productivity. Eurostat is also developing a "safe access centre" to permit academic access to CIS data from several European countries.

Finally, Europe's industrial structure, with large fixed investment in low- and medium-technology sectors, means that the goal of a marked growth in productivity over the short term cannot be attained without a significant increase in the innovative capacity of firms active in low- and medium-technology manufacturing sectors and the service sectors. Diffusion-based innovation has a strong influence in these sectors, whereas R&D-based innovation is more crucial to high-technology manufacturing. The CIS was designed to provide data on many types of innovation activities and consequently should be a key source of useful data for the European policy community on knowledge diffusion, collaboration and other areas of interest to policy. These indicators need to be provided for both R&D performing and non-R&D performing firms.

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Chapter 5

CAPTURING DESIGN: LESSONS FROM THE UNITED KINGDOM AND CANADA

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5.1. Introduction

The essence of innovation is the process of bringing to market new products or processes, which, if successful, generate new economic value. Traditionally, this process has come to be viewed as one in which the primary inputs are scientific, technological or commercial. Scientists working in university, corporate or public laboratories generate new knowledge in a variety of forms that may lead to commercializable outputs. Institutions of higher learning produce highly qualified personnel, who transmit knowledge in embodied form throughout the economy, enhancing the innovative capacity of firms. Engineers, technical workers and organizational specialists develop new production processes and improvements to existing processes. Interaction with customers and suppliers provides important knowledge inputs that further contribute to the innovation process.

However, there is an emerging consensus that innovation does not simply occur in the realm of scientific discovery. It is not the result of research and development (R&D) activities alone, and it is not necessarily associated with a particular technology. Rather, innovation takes place throughout the economy and rests on a variety of inputs, including non-technological activities. Scholars and policy makers now recognize the critical role of non-technological innovations in the creation of economic value and the competitiveness of firms, regions and nations. Yet, measurement of innovation activity rests heavily on traditional technology-based indicators, such as R&D and patent activity. In fact, these measures have been the lifeblood of national statistical agencies and other organizations responsible for capturing the importance of innovation to economic growth

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and productivity. Design is increasingly viewed as a key aspect of the innovation process, and investment in design is one of the most important assets for businesses and nations. In the United Kingdom, design use is captured through the Community Innovation Survey (CIS); however, there remains little systematic evidence of how Canadian firms, for example, are using design. Given the significant role of design in innovation and the failure of the traditional approach to measuring innovation activity to capture it, it is crucial to ask: How can the role and significance of design in the creation of economic value be captured and measured?

This chapter addresses this question by reviewing the accumulated evidence – both quantitative and qualitative – of the importance of design as a key input in the innovation process and as a source of value added in a wide range of sectors, and by suggesting some strategies for modifying innovation surveys to capture the role of design in the innovation process.

5.2. Why is design a critical input in the innovation process?

The literature on innovation has traditionally focused on the role of universities and laboratories, patenting, and scientific and technological R&D. However, design is an important and often overlooked aspect in the process of firm learning and innovation. The argument presented here for incorporating design into the measurement of innovation is consonant with recent literature on creativity and the emerging cultural economy, as well as with literature on the business use of design. Together, these provide some theoretical insight into why design requires attention in the study – and measurement – of innovation and the innovative capacity of firms, industries, regions and nations.

5.2.1. Creativity and the cultural economy

A well-established literature in the social sciences now recognizes that creative, symbolic and aesthetic content and inputs are critical in the production of goods and services in the contemporary economy (Lash and Urry 1994; Scott 2001). Within this literature there are two focal points. The first of these documents the specific industrial dynamics of a set of creative and cultural industries, including film and television, new media, fashion, publishing, music and advertising (see Scott 2001; Power and Scott 2004). Studies consistently demonstrate that firms in these creative and cultural industries are often highly innovative, yet their innovative capabilities rely less on scientific discovery and R&D in the traditional sense and more on a variety of other inputs, including artistic and design inputs. The second point, while recognizing that the creative and cultural industries are themselves important sources of innovative products and can enhance the innovative

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capacity of other industries, emphasizes the role of highly skilled, creative workers in the innovation process. Creative workers are critical to the economic performance of firms and regions through their roles in creating new products and processes and engaging in creative problem-solving (Florida 2002; Markusen, Schrock and Cameron 2004). This suggests that creative inputs (such as design) can be applied in a number of different business and industrial contexts extending beyond the creative and cultural industries.

5.2.2. The business use of design

As noted above, it is now widely accepted that creative inputs are critical in the production of goods and services. Lash and Urry (1994, 15) claim that "the design component comprises an increasing component of the value of goods," resulting in the centrality of the design process and the increasing "design intensity" of products and services across the economy. In other words, design must be understood as a strategic resource used to enhance firms' competitiveness (Power 2004). Recent literature on the "business of design" echoes this sentiment (Nussbaum 2004a). In fact, the phenomenal market success of products such as Apple's iPod and other electronics made by companies such as Sony, LG and Samsung is widely attributed to the companies' ability to use design effectively throughout their business strategies (Nussbaum 2004b, 2005). However, it is not just technology-intensive industries that have used design to secure their position in the global marketplace. Firms in more traditional industries, such as furniture, textiles and apparel, have also been able to reinvent themselves through the effective use of design (Lorenzen 1998; Rantisi 2002; Leslie and Reimer 2003).

Within the firm, design can be incorporated throughout the research and product development phase, applied to manufacturing processes to reduce costs, and used in the creation of retail environments and in branding, packaging and marketing, enabling firms to differentiate their products and services in local and global markets. Firms can take advantage of design capabilities by *a)* having their own in-house design department; *b)* employing designers as part of multidisciplinary teams in various facets of their business (*e.g.* concurrent engineering, product development, marketing); *c)* hiring freelance designers to work on specific projects; *d)* purchasing the services of an outside design consultancy; or *e)* using some combination of the above four options.

While the discussion above identifies design as critical to the innovation process, only recently have studies explicitly documented this relationship. Most of the evidence concerning the effective use of design to fuel innovation and ultimately secure value added for a firm has emerged from Europe and a

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handful of other developed and developing countries and relies on individual cases studies or one-off surveys (New Zealand Institute of Economic Research 2003; Power 2004; Danish Design Centre 2003; Design Council 2004; New Zealand Design Taskforce 2003; DIAC 2004; Gertler and Vinodrai 2004). Overall, these studies suggest that design is a critically important source of economic value, raising levels of profitability, productivity and competitiveness. The use of design can enhance sales by improving both the functional and aesthetic qualities of a product. It can also reduce production costs, simplify and enhance the sustainability of the production process, and differentiate, brand and add value to products in the market.

Despite the accumulated empirical evidence that design is an important input in the innovation process, there are few systematic studies that provide comprehensive data on the use of design across national economies. Furthermore, there is a lack both of a common definition of design and of systematic indicators of design in innovation even at the national level, making reliable national comparisons and international benchmarking difficult (Bessant, Whyte and Neely 2005; Haskel *et al.* 2005; Swann and Birke 2005; Tether 2005). This oversight can, in part, be attributed to the lack of design-related questions in the survey instruments used to capture innovation.

Most innovation surveys rely on the *Oslo Manual*, which provides guidance on data collection for a comprehensive set of innovation indicators. The current edition of the *Oslo Manual* (OECD/Eurostat 2005) provides a definition of innovation that extends beyond the development or use of various technologies. Its concept of innovation includes organizational and marketing innovation alongside established forms of product and process innovation. Yet, even with these promising revisions, the *Oslo Manual* includes only a limited treatment of design and remains heavily biased towards production and manufacturing activity. For example, design is included as an example of marketing innovation, which suggests that design is conceived only as a decorative add-on. Design is not included as a separate innovation activity or expenditure category in the *Oslo Manual*'s recommendations for coverage in innovation surveys.

Surveys in New Zealand and the United Kingdom, however, have identified design as a separate input in the innovation process. For example, elsewhere in this volume Fabling uses innovation survey data from New Zealand to show that there is a positive and significant relationship between innovation and design use.

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5.3. Challenges in measuring the contribution of design to innovation

This section examines the measurement of design in the United Kingdom and Canada. These case studies offer stark contrasts in how design has been incorporated into the measurement of non-technological innovation in these countries. They also provide lessons for analysts and policy makers on future directions for the incorporation of the use of design into the understanding and analysis of innovation processes and outcomes.

5.3.1. Design and innovation: evidence from the United Kingdom

The United Kingdom has a long-standing and active design promotion policy, and its Design Council is charged with promoting good design practice to facilitate competitiveness and innovation among UK firms. Design has traditionally been perceived in the United Kingdom as an important source of comparative advantage, and recent evidence has shown that the use of design among UK firms improves business performance and productivity (DTI 2005; Design Council 2004). However, these strengths are often underutilized, and design has not been prominent in UK innovation policies.

Within the UK context, there are two primary sources of data on the business use of design. First, the Design Council has conducted a series of landmark surveys and studies (see, for example, Design Council 2004). Second, the UK Innovation Survey (UKIS), carried out as part of the CIS, includes a small number of questions directly related to the use of design in the innovation process. Like other innovation surveys, the UKIS records the importance that firms attach to design-related intellectual property (IP), including design registration and complexity. However, in contrast to the prevailing approaches to measuring innovation that follow the *Oslo Manual*, the UKIS collects information on design expenditure as a distinct innovation input. Using these data, it is possible to develop design-related indicators that can be linked directly to measures of product and process innovation. This permits a rigorous analysis of how design-related innovation activities relate to other factors in the innovation process.

Results from the UKIS 2005, part of the fourth CIS (CIS4), provide some interesting insights into firms' use of design. While more businesses identified in-house R&D (32%) or capital expenditures (47%) as important inputs, 19% of firms identified investments in design as important to their innovation activities. Furthermore, spending on design accounted for 5% of total firm expenditures on innovation. While this was only a modest proportion of overall expenditures, it was higher than firms' expenditures on acquiring external sources of knowledge (4%), an area that receives significant attention from policy makers and academics alike. Moreover, the

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propensity to invest in design did not vary significantly across industrial sectors, with a similar proportion of firms in knowledge-intensive services, manufacturing and retail reporting design-related activity. This provides some preliminary evidence that design is an important factor in innovation across the UK economy.

However, there were a number of other design-related expenditures that could not be measured directly, since some design activities were included in other categories within the UKIS. For example, the experimental development component of R&D can include design activity. In addition, when respondents were asked to estimate their design expenditures, they were instructed to exclude any spending already accounted for in their R&D expenditures. Similarly, preparing innovations for the market accounted for a high proportion of total firm expenditures on innovation, and this activity probably included expenditures on new packaging and presentation, which are design-intensive activities.

Despite this incomplete coverage, the differences in the propensity to innovate between firms that were "design-led" and those that were "technology-led" can be examined. Design-led firms were those that either had design expenditures or used design registration or complexity to protect their innovations. Firms that engaged in R&D activity (inside or outside the firm) or assigned some importance to patents to protect their innovations were considered to be technology-led. Of course, there was substantial overlap between these two categories. Table 5.1 shows that the majority of technology-led firms were also design users. Firms that were both technology- and design-led were considered to be "design-inclusive."

Table 5.1. Overlap between design- and technology-led firms

	Not design-led	Design-led	Total
Not technology-led	59.5%	7.3%	66.8%
Technology-led	9.2%	24.0%	33.2%
Total	**68.7%**	**31.3%**	**100.0%**

Source: UKIS 2005 (CIS4) (authors' calculations).

Did firms that were design-led or design-inclusive have higher levels of innovation than technology-led firms? Figure 5.1 shows the propensity of firms in all three categories to innovate. While there was little difference in propensity to innovate between firms that were only design-led or technology-led, firms with complementary technological and design-related investment (design-inclusive) had a greater propensity to innovate.

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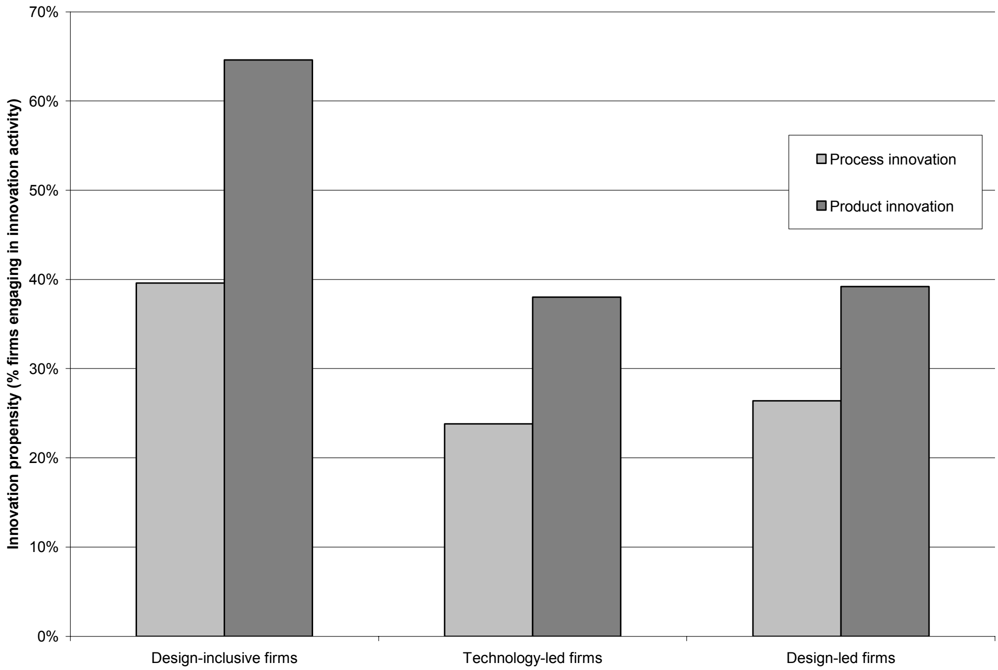
Figure 5.1. Propensity of firms in the United Kingdom to innovate, by mode of innovation



Source: UKIS 2005 (CIS4) (authors' calculations).

These complementarities can be assessed in greater depth by an examination of two conditional probabilities: the probability that a business will engage in a particular innovation-related activity (A) given that it engages in another innovation-related activity (B); and the probability that it will engage in B given that it engages in A. In general, these two probabilities will not be the same.

Table 5.2 summarizes these two conditional probabilities and shows the large number of one-way complementarities that existed between different innovation activities. A conditional probability of greater than 50% implies that the two activities complemented one another. For example, among firms that engaged in design-related activities, 71% were also involved in intramural R&D, 81% had capital and software expenditures, 76% invested in innovation-related training and 63% had marketing expenditures. However, the probability that a firm with other innovation inputs would engage in design was quite low. Overall, these findings reveal that engaging in design

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activity will lead firms to undertake other innovation activities, but the reverse is not necessarily true.

Table 5.2. Conditional probabilities of engaging in innovation-related activities

Innovation activity	Intramural R&D	Extra-mural R&D	Capital and software expenditures	External knowledge	Training	Design	Marketing
Intramural R&D	--	31%	73%*	28%	68%*	39%	51%*
Extramural R&D	82%*	--	82%*	45%	73%*	49%	60%*
Capital and software expenditures	45%	19%	--	25%	67%*	28%	39%
External knowledge	59%*	36%	85%*	--	81%*	43%	57%*
Training	49%	20%	77%*	27%	--	30%	45%
Design	71%*	33%	81%*	37%	76%*	--	63%*
Marketing	60%*	27%	74%*	31%	74%*	42%	--

* Indicates probability greater than 50%.

Source: UKIS 2005 (CIS4) (authors' calculations).

By moving beyond simple bivariate analysis and employing econometric modeling techniques, it is possible to examine the extent to which design influences innovation outcomes while controlling for the effects of other innovation inputs and other conditions of the innovation system. A series of experimental probit regressions was conducted using three different measures of the propensity to innovate as the binary dependent variable: the introduction of a product innovation (a good or service that was at least new to the firm), a process innovation, and a novel product innovation (a good or service that was new to the market). While the full analysis included variables to account for the different sources of information that respondent firms drew on in the innovation process, alongside control variables for industrial sector and region, Table 5.3 reports only the estimated parameter values for the marginal effects of a firm employing the specified innovation inputs, together with tests of significance – standard errors and z-scores.

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Table 5.3. Determinants of innovation: probit regression results

Independent variables	Product innovation			Process innovation			Novel product innovation		
	dF/dx	Std. error	z-score	dF/dx	Std. error	z-score	dF/dx	Std. error	z-score
Intramural R&D	0.170	0.010	17.25	0.055	0.008	7.6	0.138	0.018	7.3
Extramural R&D	0.037	0.012	3.04	0.036	0.009	4.2	0.054	0.019	2.8
Capital and software expenditures	0.039	0.009	4.24	0.122	0.007	17.3	-0.051	0.019	-2.6
External knowledge	0.034	0.011	3.02	0.015	0.008	1.9	0.027	0.019	1.4
Training for innovation	0.036	0.009	3.93	0.062	0.007	9.0	-0.010	0.018	-0.6
Design functions	0.059	0.011	5.46	0.033	0.008	4.3	0.071	0.018	3.9
Market preparations	0.189	0.011	18.67	0.043	0.007	6.1	0.124	0.017	7.2

Source: UKIS 2005 (CIS4) (authors' calculations).

In all three versions of the model, investment in design is positive and statistically significant. However, the relative importance of design in influencing the propensity to innovate depends on the type of innovation outcome. For example, in the case of product innovation, intramural R&D and market preparations had a larger impact than design. With regard to process innovation, design had a lower parameter value than in the case of product innovation, and capital and software expenditures had a greater impact than design. Finally, in the case of novel product innovation, design had a higher marginal effect and was relatively more important than in the other two cases, while some other inputs had a negative impact or were not significant. For example, the acquisition of external knowledge, the subject of much policy activity in many countries, did not appear significant in the introduction of novel product innovations.

Overall, the results of this analysis suggest that engaging in design is associated with significantly higher probabilities of firm-level innovation. In statistical terms, this translates into a 15–20% increase in the propensity to innovate compared with firms that do not report distinct design-related investments in the innovation process.

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5.3.1. Design and innovation: evidence from Canada

In Canada, design has not been particularly prominent within cultural or economic policy, nor has it been systematically targeted as a source of innovation for Canadian firms.[1] However, recent research has begun to fill this gap in our understanding of the contribution of design in the Canadian context (Gertler and Vinodrai 2004; Vinodrai 2005, 2006; see also DIAC 2004). For example, Gertler and Vinodrai (2004) have studied the contributions that design skills make within a wide range of established and emerging sectors. Figure 5.2 shows that the growth of Canada's design labour force (defined occupationally to include industrial, interior, graphic, fashion, theatre and other designers, as well as architects and landscape architects) outpaced that of the overall labour force between 1987 and 2002.[2] Canada's design workforce grew at a rate of 3.7% per year, compared with only 1.7% for the overall labour force. Figure 5.3 compares employment in design occupation*s* with employment in Canada's design *industry* between 1987 and 2002. It shows that, overall, employment in the design workforce (defined occupationally) grew at a faster rate than employment in the design industry, suggesting that industries outside the design industry were availing themselves of design-related expertise by employing designers *directly*. Figure 5.4 confirms this finding by showing the sectoral distribution of people working in design occupations in 2001. Fewer than half of all designers worked in specialized design firms found in professional services. In other words, designers were employed in a wide range of traditional and emerging industries.

1. It is worth noting that, in contrast to most Canadian jurisdictions, Montreal and the province of Quebec have successfully incorporated design into their economic development strategies (Leslie and Rantisi 2006). In Ontario, design has only recently been acknowledged as an important source of innovation and value added (Design Exchange 1995; DIAC 2004; City of Toronto 2006).

2. While the analysis presented in Gertler and Vinodrai (2004) uses data for Ontario, this chapter offers a similar analysis conducted at the national level. In general, the results are quite similar.

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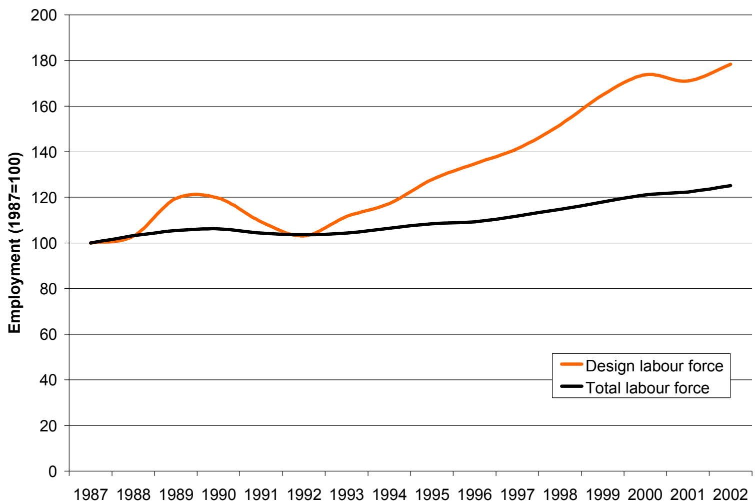
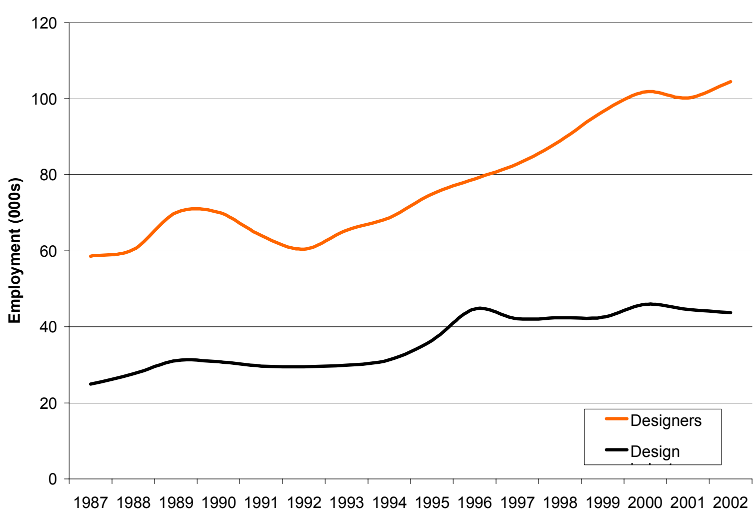
Figure 5.2. Indexed design employment in Canada, 1987-2002



Source: Statistics Canada, Labour Force Survey, 1987–2002 (custom tabulations).

Figure 5.3. Employment in design occupations vs. employment in Canada's design industry, 1987-2002



Source: Statistics Canada, Labour Force Survey, 1987–2002 (custom tabulations).

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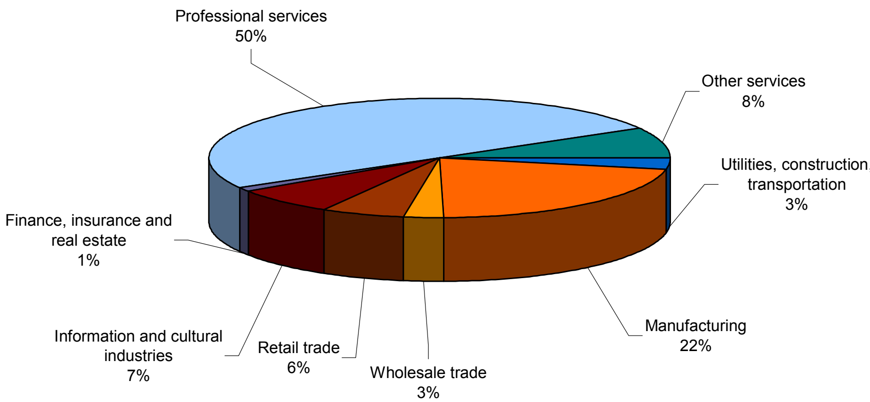
Figure 5.4. Sectoral distribution of designers in Canada, 2001



Source: Statistics Canada, Census of Population 2001 (authors' calculations).

The importance of this finding is emphasized elsewhere. Vinodrai's research (2005, 2006) explores how design expertise is transferred between the design industry and other sectors of the economy. Through an analysis of employment dynamics, contractual relationships, freelance activity, and the longitudinal labour market mobility of industrial and graphic designers, she demonstrates how designers work in various settings over the course of their careers, both in the design industry and in other industries. Overall, the findings from Vinodrai's analysis (2005) have led her to conclude that design expertise and knowledge developed in working for a variety of employers can be transferred between firms and industrial sectors via labour market mobility. Firms benefit from designers' circulation in the labour market, since designers can bring new knowledge into the firm, thereby acting as an important source of embodied knowledge, in much the same way as engineers, scientific researchers and technical workers (see also Angel 1991; Almeida and Kogut 1999; Henry and Pinch 2000).

The empirical findings reviewed above suggest that Canadian firms in many industries are hiring designers and that this practice has become more widespread in recent years. However, it remains an open question as to how *effectively* Canadian firms are using design expertise. It is also imperative to differentiate between users and non-users of design to determine if some firms and/or industrial sectors have made more extensive and effective use of design, as well as how and where design expertise is being utilized and applied within firms.

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Unlike the situation in the United Kingdom, there are few comprehensive data sources in Canada that explore the various aspects of design or that attempt to understand the business use of design. The quantitative analysis presented above relies on data from Statistics Canada's Census of Population and Labour Force Survey (Gertler and Vinodrai 2004). These data sources enable analysts to understand the socio-economic and demographic characteristics of people working in design occupations or in the design industry. However, they do not provide information about the industrial dynamics of these sectors, nor do they focus on how design is being utilized within particular industries. Furthermore, these data are cross-sectional and therefore tell very little about employment mobility and other factors that can be revealed through longitudinal analysis. Vinodrai's analysis (2005, 2006) relies on a qualitative methodology to understand the longitudinal labour market dynamics of designers.

The only comprehensive, national survey that explicitly examines the business of design in Canada is the Survey of Service Industries: Specialized Design, which has been conducted annually since 1998 (Statistics Canada 2007). This survey is based on a sample of establishments in the specialized design services industry, which includes: landscape architectural services; interior design services; industrial design services; graphic design services; and other specialized design services.[3] The survey provides basic information about the number of establishments, their size and their sources of revenue (design consultation, design services, project management, other), as well as some broad-brush information about the types of clients (government, businesses, individuals and/or families) and where these clients are located (same province, different province, international).

However, there are a number of drawbacks to the survey. First, there is no detailed geography of the design services establishments below the provincial level. Given that design employment tends to cluster in metropolitan areas, this is a significant shortcoming. Second, there is very limited information about the clients and users of design services, including their industrial or sectoral classification and the nature of the relationships between design service providers and design users. Hence, leading and lagging sectors in the use of design services cannot be identified. Third, the survey fails to capture in-house design activities within non-design firms. Given the evidence that this activity has been increasing in relative and

3. Statistics Canada was able to identify readily establishments in the specialized design services industry only with the adoption of the 1997 North American Industry Classification System (NAICS). Prior to this, the Standard Industrial Classification (SIC) did not allow for the easy identification of firms in the design services. Architectural firms are covered under a separate survey: the annual Survey of Architectural Services (Statistics Canada 2006a).

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absolute terms in recent years – borne out by the key finding that roughly half of all designers do not work in design firms – this too is a critical gap in the understanding of design use in the economy. Finally, there are few direct ways to assess the business practices and innovation performance of firms in the design services industry, and to link these to their economic performance.

Statistics Canada's Survey of Innovation solicits information about product and process innovation in manufacturing, natural resources and specialized services firms. In fact, the sample for the Survey of Innovation 2003 (Statistics Canada 2004) included establishments in the industrial design services industry. While including this industry in the survey had the advantage of revealing the sources of innovative ideas and the level of innovation for establishments in one part of the design industry, it did not capture how design was being used in other industries.

The Survey of Innovation gathers useful data on the sources of information for innovation activities, both internal and external to the firm.[4] There is, however, no explicit recognition of the role that designers (in-house or from outside the firm) play in enhancing the innovative potential of a firm. Furthermore, while the Survey of Innovation links innovation activity to firm performance (measured in terms of sales revenues, quality, process improvements, productivity and market share, *inter alia*), it does not shed light on the impact of design inputs on firm performance. In other words, it leaves unaddressed a key question: How does design add value to firms' products and services and enhance firms' competitive success?

Despite these shortcomings, the Survey of Innovation has considerable potential as a tool for addressing such questions. Perhaps its most important characteristic is the breadth of its target population, since it covers a wide range of sectors in the Canadian economy.[5] It includes both newer and older industries, and incorporates both more and less knowledge-intensive forms of economic activity. Such a sample structure would support an analysis of

4. For the Survey of Innovation 2005 (Statistics Canada 2006b), the internal sources of information included: R&D staff; sales and marketing staff; production staff; management staff; and other plants or R&D laboratories in the same firm. External sources included: suppliers; clients or customers; competitors; consultants; commercial, public or non-profit R&D laboratories; universities and colleges; conferences and trade fairs; scientific journals and trade publications; investors; industry associations; the Internet; and experienced entrepreneurs.

5. Each of the past Surveys of Innovation has targeted a slightly different sample. The Survey of Innovation 1999 (Statistics Canada 2001) covered approximately 6 000 businesses in the manufacturing, construction and natural resources sectors, while the Survey of Innovation 2003 focused on approximately 1 700 establishments in specialized services (including industrial design). The Survey of Innovation 2005 returned to the broader coverage of the 1999 survey, with a sample of approximately 8 000 firms.

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how the use of design varies by sector, firm size and other pertinent characteristics.

A small number of new questions could be added to the Survey of Innovation to measure the *prevalence* of design use. They would gather information on:

- The number of full- and part-time, as well as permanent and contract, design staff employed in-house;[6] and
- The use of designers external to a firm (freelancers, design firms), measured in terms of the dollar value of expenditures to purchase their design services.

Relatively modest, incremental modifications to existing Survey of Innovation questions[7] would allow the collection of vital information concerning the *importance* of designers in contributing to innovative ideas, by gauging:

- The importance of design staff in-house in generating innovations; and
- The importance of external design firms and freelancers in generating innovations.

More probing analyses exploring *how* design contributes to the innovation process would require new questions, such as:

- At what stage in the innovation/production process is design used:
    - initial stage of product/process development;
    - later stage (*e.g.* customization);
    - packaging, marketing?

Additional questions could explore the link between design activity, innovative capacity and firm performance more explicitly. For example, a national study in the United Kingdom commissioned by the Design Council (2004) asked firms across the economy a number of questions related to the use of design within their firm:

6. This could be further disaggregated by type of designer, using accepted occupational categories such as industrial, interior, graphic and fashion designer, architect, landscape architect, and other.

7. Question 25 in the Survey of Innovation 2005 asks: "During the three years, 2002 to 2004, how important to your plant's innovation activities were each of the following information sources?"

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- How have design, innovation and creativity contributed to your business over the last three years?
- Has design become more important in maintaining your competitive edge over the past 10 years?
- What role does design play in your business?
- How is design used in new product or service development?
- What are your main reasons for not using more external design expertise?

5.4. Learning from the United Kingdom and Canada

This chapter has reviewed the accumulated arguments, both conceptual and empirical, concerning the growing importance of design as a determinant of firms' innovative capacity and competitive success. It is clear from this review that the economies of countries in the Organisation for Economic Co-operation and Development (OECD) are becoming increasingly reliant on the use of design as a way to enhance the market success of goods and services. As part of the more general trend towards identifying and exploiting non-price forms of competition, firms in many of these countries appear to be discovering the importance of design as a source of economic value.

While some countries – most notably, the United Kingdom and countries in Northern Europe – have led the way in devising means to document this phenomenon statistically, Canada and other OECD countries have not kept pace. This chapter's exploratory analysis of the Canadian case, using available employment data reported by occupation and industry, as well as more qualitative information, appears to indicate that design activity is expanding rapidly in Canada, and that it is spreading well beyond the design industry itself. This is in keeping with evidence from other OECD countries (Danish Design Centre 2003; Power 2004). Yet, the current national surveys of innovation do not collect information on a systematic basis that would allow the documentation of the prevalence of design use and its importance to the innovation process in sectors across the OECD economies. Moreover, the current approaches to documenting the structure of and interrelationships between elements within most national innovation systems are hampered by an unduly restrictive list of participants: designers are conspicuous by their absence from the list of agents of innovation and sources of innovative ideas.

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Given this mounting evidence, it is clear that the existing panoply of indicators of innovation activity needs to be modified to capture the growing importance of designers and design inputs to the innovation process. In other words, those actors who are responsible for providing design inputs need to be counted among the usual list of agents – scientists, engineers, managers, technical/skilled workers, university and private researchers, consultants, customers and competitors – who are routinely regarded as active participants in the innovation system. How, then, can the extent and impact of design's contribution to the innovativeness and competitive success of firms be measured? How can the ways in which firms are integrating design into their innovation and production practices be assessed?

The review of the UK evidence indicates some promising directions. The survey instruments and questions developed for the UKIS and by the Design Council offer some important correctives to the measurement of innovation activity that account for the role of design. Clearly, adding questions similar to those used by UK researchers incrementally to existing surveys of innovation (without the offsetting deletion of other survey questions) increases the risk of adding unduly to firms' burden of response. Nevertheless, the growing body of international evidence concerning the strategic importance of design across the economy warrants a serious reconsideration of the content and structure of innovation surveys in order to reflect these recent developments. Furthermore, the linkage of innovation survey data to other measures of firm characteristics and performance, including those collected through other establishment-based surveys, could allow the determination of the extent to which a firm's use of design is correlated with export activity, growth in sales, employment and market share, and other key performance outcomes.

If the secular trends documented in this chapter are indeed as fundamental and widespread as they appear to be, then it is of critical importance for high-wage, developed economies such as the OECD countries to collect information on design use and its role in innovation. This chapter has argued that a number of modest but significant incremental modifications to existing national innovation surveys would go a long way towards achieving this goal, while also complementing the useful information already available through other national surveys and official statistical data sources, such as national censuses. Given the growing recognition of non-technological sources of innovation, such as design, this would seem to be a good time to initiate a rethinking – and redesign – of existing data collection instruments.

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Chapter 6

ENRICHING THE INDICATOR BASE FOR THE ECONOMICS OF KNOWLEDGE

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6.1. Introduction

This chapter addresses the issue of the development of indicators aimed at providing a measurement base with both breadth and depth from which research in the "economics of knowledge" can benefit. While initial attempts at quantification in the area of the knowledge economy were based on both national accounting (Machlup 1962) and growth accounting (Abramovitz and David 2001), the use of indicators with a direct bearing on knowledge (Jaffe and Trajtenberg 2002) is becoming the dominant approach. There is no summation (or composite value), as in accounting, but rather a collection of available statistics on several dimensions of knowledge, such as scientific and technological knowledge, innovation inputs and outputs, and organizational practices.[1] The strength of this latter approach is that, depending on the quality of the indicators, it allows a genuine grasp of the phenomena of knowledge and innovation under consideration.

The economics of knowledge is now at the point where it has the potential to become a strong, empirically disciplined science, depending on whether enough progress can be made on developing the underlying data and the indicators ensuing from them. This chapter argues that the economics of knowledge is at a crossroads, and it uses the development of knowledge management indicators as an illustration of this.

1. See Godin (2007) for the development of this classification with regard to different approaches to "measuring knowledge."

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6.2. The history of knowledge management indicators

Knowledge management (KM) is generally considered as a set of new organizational practices that seems to be of broad relevance to the knowledge economy. It covers any set of practices or processes intentionally designed to optimize the use of knowledge – that is, to increase efficiency of allocation in the areas of knowledge production, distribution and use.

When some statisticians, economists and analysts started to become interested in studying KM, information about it consisted mainly of anecdotal evidence, success stories and a few business studies done by consulting companies. Following are accounts of a couple of successful initiatives that first started to attract attention through publication in business journal articles and in such influential books as *Working Knowledge* (Davenport and Prusak 1998, xiv):

> At Hoffman-LaRoche a knowledge management initiative in 1993–1994 reformed the process of developing new drug applications, the voluminous, complex documents that must be submitted to the FDA [Food and Drug Administration] before any new drug can be approved and brought to market. In significant measure because of the initiative, applications and approval for several new products now take many months less than the usual time to complete, at a saving of $1 million per day.
>
> At Hewlett-Packard, the amount of product knowledge required to effectively use and support complex computer products has exploded. So in 1995, the company implemented a knowledge management tool called "case-based reasoning" to capture technical support knowledge and make it available to personnel around the world.

In their introduction, Davenport and Prusak claim that KM is a great source of competitive advantage, enhancing both the efficient allocation of this precious resource and companies' innovative capabilities. There is no way of knowing if they are right. However, consultants and gurus are quick to claim that KM is the unique solution to all problems encountered in the course of a firm's daily operations.[2]

Economists usually like to know a bit more than this about a new practice or technology that starts to be widely diffused in the economy. Since many firms are spending money on KM, one would expect them to be getting something in return. But spending money on "something" is hardly a

2. This is not, of course, a reference to Davenport and Prusak, who have written a useful book that articulates their considerable knowledge, experience and practices in this area.

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reliable predictor of its returns. How do economists know if KM is more than a fashionable social technology when there is no evidence that implementing it is efficacious? Is KM simply a new managerial discourse used to renew motivation and commitment among participants in the capitalist enterprise (Boltanski and Chiapello 1999) or is it an effective organizational innovation that has the potential to increase labour productivity?

To answer these questions, economists have to design an applied research program that obviously involves the building of indicators (Foray 2004). The quest for broader and more systematic empirical information relating to KM entails a four-step process:

- Conceptualization: it is necessary to examine the literature to see whether there are economic reasons to manage knowledge. The idea is to search for and articulate stylized facts about knowledge as a commodity to see whether a good economic case can be made for a private company to invest in KM.
- Data collection: data to highlight the various dimensions of the phenomenon are needed. This is a crucial issue. A special feature of the economics of technical change, innovation and knowledge is that it calls for large amounts of data, much of which is rather unconventional for economists (Trajtenberg 1990). This feature reflects both objective econometric requirements and the conviction that, if the phenomena of knowledge and innovation are to be understood, the only choice is to seek data with a direct bearing on them. This is less obvious than it sounds: economists are reluctant to engage in raw data collection, trying instead to compensate for the scarcity of data with econometric ingenuity (incentives in the profession are set accordingly); the prevailing conception of legitimate economic data is rather narrow and conservative. This may be justifiable in other areas of economics, but not in the realm of innovation and technological knowledge.
- Answering the big question: does KM matter in economic terms? That is, would an increase in inputs and resources for KM lead to more outputs? Unless this question is answered, there is no point in proceeding to the final step.
- The manipulation of incentives and inputs to achieve particular goals – the usual prescription of economics (Griliches 1962).

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6.2.1. Stylized facts about knowledge as a commodity

Clearly, many views on knowledge as a commodity can be found in the literature. Several of these can be used to build an economic case for implementing KM practices.

Knowledge is a product of learning by doing: Many innovation activities occur "on the floor" or on-line (as opposed to off-line), through the mechanism of learning by doing. In this process, innovation is not the main goal, but may nevertheless occur as a joint product of the activity. The process can even entail an experimental approach (people plan experiments on-line and draw conclusions, new options are generated and variety ensues). However, since the main goal is to deliver a service or produce a good at the end of the day, the learning process can conflict with a worker's normal expected performance. Thus, there is a role here for KM in the organization of proper conditions to manage this conflict and to promote experimental learning in the daily operational context of a manufacturing plant or service operation.

Knowledge is like a fixed cost: A piece of knowledge needs to be produced only once and can be used repeatedly by as many people as want to use it. The production of knowledge is like a fixed cost in the production of goods and services. Fixed costs are by definition a source of economies of scale in production, which raises various strategic and policy issues. Again, an economic case can be made for KM, this time as a method for seeking some kind of optimal use of knowledge.

Knowledge needs to be reinforced: Evidence in the psychological literature shows that, when people are interrupted in the performance of a task, their ability to remember it is diminished. Hirsch (1952) found that, when a job was resumed after an interruption, it was at a lower level than that attained prior to the interruption. The knowledge derived from learning by doing quickly loses its value and, if the stock of knowledge is not replenished by continuous production, it depreciates rapidly. A case can be made here for KM as a method of organizing mechanisms explicitly to aid the memorization and maintenance of existing knowledge and to minimize accidental loss of inventions.

Knowledge is difficult to transfer: As von Hippel (1994) puts it, knowledge is "sticky." Stickiness raises a number of issues in terms of the organization of knowledge production and the integration of pieces of knowledge that have been produced in different places.

Knowledge is tacit: Typically, knowledge and expertise are neither articulated nor codified. Tacit knowledge resides in people, institutions or routines. The fact that it is tacit makes knowledge difficult to learn,

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memorize, recombine and transport. One solution, and this again makes an economic case for KM, is to codify knowledge: the knowledge is recorded on a medium. This entails high fixed costs, but all KM operations can then be performed at a very low marginal cost. Codification, as a KM procedure, increases the memory capacity of an organization and creates learning programs for new workers.

The last stylized fact found in the literature does not articulate any characteristic of knowledge as a commodity. Rather, it is the need for organizational structure and practices to complement the investment in information and communication technology (ICT). There is now considerable evidence that "organizational complements" – such as business processes, decision-making structures, incentive systems, human capital, corporate culture and KM – play an important role in a firm's ability to realize value from its ICT instruments (Brynjolfsson and Hitt 2005). The act of acquiring and maintaining these organizational complements is a real cost to the firm, but also a potential source of significant value when combined with appropriate investments in technology. KM practices appear to be an important organizational complement, playing a key role in increasing private and social returns from ICT investments. As Milgrom, Qian and Roberts (1991) put it, the deployment of ICT and the adoption of KM practices are mutually complementary, with each making the other more attractive. It is through the development of such complementary activities that the Solow paradox has been resolved.

Thus, there are plenty of economic motivations and arguments for private companies to design, implement and develop KM practices. The literature dealing with the main features of the economics of production and transmission of knowledge clearly builds an economic case for KM. It can be inferred from this that KM is probably more than just a managerial fashion; rather, it is a social technology that is likely to have a positive impact on efficiency, innovation and productivity. There are therefore grounds for proceeding to the next step, data collection.

6.2.2. Data collection

Good economic research depends on the generation of appropriate and reliable economic data. If economists want to comment on the economics of KM, the only way to do so is to have a measurement base on which research in the economics of KM and innovation can be founded. The Organisation for Economic Co-operation and Development (OECD) KM survey, the result of an intense collaboration between Statistics Canada and the OECD, was developed in 2001 and 2002 to:

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- Create a systematic database on the diffusion of KM practices in some OECD countries;
- Obtain some leverage in terms of international comparisons by using the OECD mechanism, which consisted of contracting with national offices to do the work within a common framework of statistical guidelines;
- Contribute to the stabilization/standardization of the conceptual categories and terminology of KM; and
- Create some infrastructural knowledge related to the survey (terminology, categories, questions, test results), so that more countries and researchers could use it to undertake further studies and analysis.

The survey, whose methodology, national studies and topics are extensively described in OECD (2003), produced important results. It demonstrated that it is possible to produce some aggregate measures of KM implementation and diffusion, and to build indicators of firms' behaviour with regard to KM; and it generated a series of results about the diffusion of KM, the effects of firm size and technology, firms' priorities in terms of KM practices and purposes (acquiring and sharing knowledge, human resource management, etc.), and the complementarities between KM and other innovation activities (see, in particular, Earl 2003, 2005; Earl and Gault 2003; Edler 2003; Kremp and Mairesse 2003; Lhuillery 2006).

6.2.3. Answering the big question

Is KM of significance in economic terms? The data have shown that KM practices are widely adopted within the private sector. However, there are plenty of cases of innovations in social technologies that have been extensively adopted over a short period, while no clear evidence about their economic impacts has ever been produced (Nelson 2003).

Kremp and Mairesse (2003) used French data from the third Community Innovation Survey (CIS3) to study whether there is a relationship between KM intensity and outputs (in either innovation or productivity). The evaluation of the economic impact of a new practice or technology is difficult, since the same firm cannot be observed simultaneously with and without KM. If a firm that has implemented some KM practices is studied, there is no direct way of discovering what the outcome would have been if the company had not implemented KM. There are several indirect approaches, however: for instance, one approach is based on the assumption that, as long as two groups of firms share the same characteristics, it is acceptable to compare the treated group (with KM) with the untreated group (without KM). Kremp and Mairesse, however, used the opportunity afforded by a very large dataset (6 000 firms) to search for statistically significant

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correlations between an indicator of KM intensity and output and outcome variables (innovation, patenting, labour productivity) in a cross-sectional econometric study. Their findings show the statistical and economic significance of the estimated impact of KM intensity (2003, 158): regardless of size, industry, involvement in research and development (R&D) and whether they belong to a group of firms, companies tend to innovate and patent more extensively if they have adopted KM policies. All else being equal, when KM intensity increases, the propensity to innovate, as well as innovation intensity, also increases significantly; the same is true for patenting. The estimated impacts are quite substantial and, in spite of all the usual reasons of econometric misspecification that potentially apply here, the authors claim that the results remain statistically informative. At a minimum, they reflect underlying positive correlations, conditional on a fair number of relevant factors. The authors' tests and results for the relation between KM intensity and labour productivity provide a similar picture of the positive effect of the new organizational practice on economic variables. As Kremp and Mairesse point out, all these results do not indicate causality, although such a causal link seems a priori more likely than not.

These results provide some detailed evidence for the view that intangibles like KM and other organizational complements are a crucial part of the explanation for the recent surge in productivity in OECD countries. They also encourage economists to extend the research towards incentive mechanisms and the social arrangements that would be most conducive to increasing KM intensity as an important driver of innovation and productivity.

6.2.4. Incentives

The fourth and last step in the process deals with the existence and identity of factors and incentives affecting the level of KM activities. It is instructive, for example, to consider the issue of employees who are encouraged, through some kind of rewards mechanism, to write, codify and share documents. These employees therefore have to undertake two different tasks (their normal work and the KM activity), and they have to choose a level of effort for each. The firm's challenge is to offer incentives to elicit the optimal level of effort. The theory of incentives in a multi-task setting claims that it is necessary to balance incentives optimally across tasks; otherwise, employees will inefficiently allocate greater effort to those tasks that offer them the highest return. On the basis of this general observation, it is possible to model optimal incentive structures for the effective implementation of KM practices.

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6.3. Market failures for indicators

The OECD survey provided the international economic and policy community with some useful results concerning KM:

- There is a strong economic case for implementing KM in private companies;
- The production of aggregate measures of various aspects of KM diffusion, as well as of firms' behaviour vis-à-vis the management of this asset, is possible;
- Some statistical tools have been tested and improved and are publicly available (Earl and Bordt 2003);
- The estimated impacts of KM on innovation and productivity are quite substantial; and
- It would be useful to proceed further towards the manipulation of incentives and inputs to achieve particular targets in terms of KM intensity.

However, the proof of concept – *i.e.* the demonstration that the questions are relevant and aggregate measures are possible – is by no means sufficient to ensure that new indicators are accepted internationally and the data collection is routinized.

As they exist now, the KM indicators (*i.e.* indicators of KM intensity) are by no means ideal. An ideal indicator has to pass successfully the tests of precision, absence of bias, stability over time, comparability across different classifications, resistance to manipulation, aggregation and cost (Jaffe 1999).

It is obvious that a new indicator will be improved if enough time is allowed for it to be used and tested, and for people to use it routinely for both data collection and data interpretation. While some indicators of R&D are now close to ideal (at least for those who believe in the importance of R&D in innovation and economic growth), the first attempts at R&D indicators required improvement.

This shows that the first phase of building and using a new indicator, which has demonstrated its relevance and some practical merits, is extremely perilous, often involving insurmountable obstacles. This is a selection phase, characterized by market failures that stem mostly from problems of "increasing returns":

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- The creation and initial use of an indicator entail high fixed costs (research, initial tests, survey design and implementation), which are difficult for a small group of initiators to bear;
- The wide diffusion of a new indicator requires strong network externalities: the more interesting the indicator and the higher the number of "users" (statistical offices), the greater the number of additional users it will attract;
- The successful implementation of a survey involves strategic complementarities at the institutional level among researchers, statisticians, policy makers and the business community, which exist only partially at the start (the section of the business community that has to be mobilized as a source of information about KM is different, for example, from that which provides information about R&D);
- There is a time series effect: "old indicators" create a double value for the corresponding survey done at time n – the value of collecting data at time n + the value of not discontinuing the time series; this second value is, of course, 0 in the case of a new indicator;
- Finally, a successful indicator is a "code," which enhances the efficiency of communication and information-processing procedures among a large number of economic agents. But a code represents an especially durable form of capital, and when individuals learn a code it is an act of irreversible investment on their part (Arrow 1974; David 1994). The need for codes that are mutually understandable within organizations causes individuals and groups to become specialized in the information that can be readily transmitted by the code and to ignore information that would require a different code to be absorbed. Since the code is part of the organization's capital, it will be modified only slowly over time.

All these features correspond to some form of increasing returns in the development and consolidation of new indicators. It is not necessarily the case that the international community will adopt an indicator, even if the proof of concept has been produced. As in any case of technological competition that entails uncertainty and increasing returns, the best will not necessarily win. The winners will be those that succeed in achieving enough momentum to benefit from the dynamic of increasing returns, while keeping other good candidates out of the market.

A further complication arises from a problem of scarce resources, which includes not only money, but also attention from policy makers (to interpret new indicators that might change their policy perspective) and time from the business community (to complete questionnaires). This means that a new indicator will often be imposed at the cost of existing ones. This creates

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more difficulties, since the existing indicators are somewhat closer to the ideal than the new one.

It is obvious that there is little room to correct these market failures. The initial phase of implementation is a decisive one. It should involve multiple interactions among researchers, statisticians and official survey administrators, policy makers and, of course, the business community as the source of information. This phase operates as a sort of filter through which very few new indicators pass successfully. Accounts of survivors of this phase show that success entails the creation of a coalition of stakeholders that rapidly recruits strategically valuable new members, a process resembling the creation and eventual domination of an "epistemic community."

6.4. Conclusion

The economics of innovation and technological knowledge is primarily an empirically disciplined science. The OECD KM survey, as well as many other examples relevant to this discussion,[3] shows the need for applied economists to learn and gather the facts of technology and organization themselves. Data based on remote proxies are inadequate. An ongoing challenge for applied economists in the area of innovation is to enlarge the scope of empirical material that economists will regard as legitimate, and perhaps even routine, in applied research. This effort is necessary if the economics of innovation and technological knowledge is not to remain purely abstract, but is able to link theory to practices. By doing this, it will be able to provide both private-sector managers and policy makers with information about the aggregate economic impacts of new organizational and human resource practices, new business methods and new discovery technologies.

However, the case of the development of KM indicators shows that this is a difficult process. The production of a proof of concept is no guarantee that the indicator under consideration will be adopted internationally in what has become the conventional manner. For example, there is no internationally accepted manual of KM indicators similar to the *Frascati Manual* (OECD 2002) for R&D indicators.

Nonetheless, KM practices, as systematically used by private firms, are clearly a central organizational concept in the knowledge economy, and it is therefore important to measure firms' behaviour in this area. In addition, KM and other new human resource practices are complementary investments that are larger than investments in ICT itself. However, they go

3. The measurement of user innovation is another case in point (see von Hippel elsewhere in this volume).

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largely uncalculated, and the task of measuring more effectively the intangibles that are increasingly important to knowledge-driven growth and firms' performance remains incomplete.

The challenge of developing a measurement base from which to study KM at the firm level is, therefore, still to be faced, and there is a need for stronger political commitment, as well as more interaction among statisticians, economists, policy makers and the business sector.

However, the great success of the development of indicators from firm-based surveys of innovation activity, as implemented in a number of European countries and elsewhere (including Canada), offers a reason for optimism. The success of the Community Innovation Survey (CIS) is easily explained. Innovation is an old and prestigious economic concept, familiar to economists (not only Schumpeterians). Little effort was required to attract the interest of policy makers, who were well aware of the importance of evidence about innovation performance, and it was equally easy to find the section of the business community in charge of innovation management in firms. Thus, the network of potential users was initially quite large and was strongly supported by powerful institutions. The strategic complementarities among the various stakeholders already existed, since they were quite similar to those for R&D data collection. Only the fixed cost of launching the survey could have been a problem, but this proved surmountable since a large number of institutions were willing to share the burden.

As part of this development, the most recent revision of the *Oslo Manual* (OECD/Eurostat 2005) – which is the "codebook" for innovation indicators – extends its coverage to new types of innovation, including "organizational innovation." This category is obviously broader than KM, but is clearly related to it. Most of the examples of organizational innovation in business practices are actually KM practices (OECD/Eurostat 2005, 51). More specifically, KM measurement is discussed throughout the manual (OECD/Eurostat 2005, 24, 77, 87 and 125), drawing on the work in OECD (2003). Within the series of Community Innovation Surveys, the four questions about the adoption of KM practices, used in Kremp and Mairesse (2003) to estimate KM intensity, have been used again in CIS4.

A final reason to be optimistic about the development of a rich indicator base for the knowledge economy is that, even in the absence of a large international survey using standardized procedures for data collection on KM, empirical studies on the economic impact of KM (as well as of other new human resource practices) are proliferating (see Hall and Mairesse 2006), all of them concluding that such new practices enhance performance (see Shaw 2004, for a survey). Of course, all these studies are based on partial surveys, ad hoc datasets and datasets that are not purpose-designed.

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Hence, the studies are extremely costly and have a poor potential for international comparisons and benchmarking. However, although each of these studies seems vulnerable and open to criticism on many counts when considered alone, the overall convergence of their results is quite convincing.

The success of the CIS, as well as the increasingly large body of empirical research on KM and organizational innovation, based on firm-level data, show that the future of the economics of knowledge as a strong empirical discipline is promising, and that the objective of enriching its indicator base is achievable.

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Chapter 7

TOWARDS UNDERSTANDING THE IMPACTS OF SCIENCE, TECHNOLOGY AND INNOVATION ACTIVITIES

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Statistics Canada

7.1. Context

For centuries, science, technology and innovation (STI) activities have been one of the driving forces of economic and social change. The transformation of the developed economy from one based on natural resources to a globally integrated system based on knowledge and information could not have occurred without the adoption of scientific principles or the implementation of innovative technology. Similarly, STI activities have accelerated growth and brought about social change through the movement of people, goods and services, and through an increased capacity to generate, transmit and use STI knowledge.

Despite the importance of STI activities, much of the existing information about them relates only to inputs: for example, who is involved in which activity and what is the nature of that activity? These basic measures are essential for tracking who is doing what, where, how and why. However, they are less useful for assessing the outcomes and impacts of STI activities. Although some current indicators do provide information on the immediate outputs of STI activities, the focus is now shifting to more sophisticated measures of the potential value added and costs of STI, and their longer-term implications for the economy and society.

This chapter presents Canadian initiatives geared towards understanding the social and economic impacts of STI activities. In particular, it discusses measures currently used by Statistics Canada and other agencies to describe STI activities and offers new approaches to understanding their impacts. A discussion of the need for and challenges of impact indicators is also included, as well as recommendations for the future direction of this work.

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7.2. The need for indicators

Indicators serve many purposes. They can be linked to policy issues through analysis in order to guide decision-making; they can be used to monitor and evaluate programs; and they are needed for benchmarking and comparison purposes, both over time and across countries. Whatever the intended purpose, indicators provide relevant information about the state of the economy or society through the use of statistics.

Whereas activity indicators are needed for descriptive analyses and decisions about funding, and indicators of linkages are important for illustrating how various parts of the economy and society are interconnected, outcome and impact indicators are crucial for evidence-based policy, resource allocation and accountability requirements (Gault 2006).

7.2.1. Developing indicators

For relevant indicators to be developed there must be a demand for them. They must feed into the policy process, evolving over time and according to changes in policy priorities. For Statistics Canada, this means maintaining a relationship with the main users of the statistical and analytical outputs, including policy departments, key stakeholders and international bodies, such as the Organisation for Economic Co-operation and Development (OECD).

Canada has been engaged for some time in the development of indicators and the collection of data for a number of STI activities, including research and development (R&D), innovation, intellectual property (IP) and its commercialization, and technology adoption and diffusion. Work began with programs intended to obtain insights into inputs and outputs of STI activities, which then led to a broader focus on STI linkages and outcomes (for example, the uses of information and communication technologies (ICTs), determinants of innovation, new technology adoption and business practices). There is now a push to move even further towards understanding the impacts associated with STI.

All along, Canada has contributed to, and benefited from, the development of internationally agreed guidelines, definitions and classifications for the measurement of STI through active participation at the OECD's Working Party of National Experts on Science and Technology Indicators (NESTI) and the Working Party on Indicators for the Information Society (WPIIS). International collaboration and coordination are essential if work on STI outcomes and impacts is to continue to advance.

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7.3. The challenges of assessing impacts

Impacts are not easily defined or measured. Work in this area is still in the early stages, and there are no established frameworks on which to build. One of the more obvious difficulties is the fact that impacts can take some time to emerge into observable phenomena. In some cases, the outcomes and impacts of STI activities have not yet been fully absorbed into the economy or society. For example, it is clear that Internet use has brought about changes in social behaviours, but the broader impacts of these changes are still unfolding.

In addition, impacts are often difficult to identify and cannot easily be traced back to their origins. Impacts are also multi-dimensional: they can be both positive and negative; they can be direct or indirect; they can vary among actors (*e.g.* individuals, firms); they can affect the economy, society and more; and they can affect the environment surrounding STI activities that results from changes in STI policy or strategy (Statistics Canada 1998a).

Finally, impacts cannot be measured in the same way as activities. They are better understood through a combination of surveys and analytical techniques, rather than through direct assessment from survey instruments alone. This approach is useful for identifying the linkages and outcomes of STI activities, which can then be used analytically to shed light on impacts. Some examples of analytical techniques used for this purpose include econometric modeling (Klassen and Carnaghan 2006; Sciadas, Clermont and Veenhof 2005; Veenhof 2006) and microeconomic simulation modeling (Wolfson 1995). A case study or data linkage approach (Baldwin and Sabourin 2001, 2004) would also add value to the study of impacts.

7.4. A systematic view of STI indicators

The first and most basic step towards understanding impacts in the context of STI indicators is establishing a framework. A framework not only helps to guide statistical work and identify measurement gaps, but also provides a better understanding of how different indicators are connected.

7.4.1. A framework for STI indicators

Shortly after the first Blue Sky conference, Statistics Canada – in consultation with Industry Canada, members of the Advisory Committee on Science and Technology Statistics and its Working Group, and others – developed a framework for a statistical information system for science and technology (S&T) (Statistics Canada 1998a). The structure of the system comprises an *actor* or set of *actors* engaged in *activities*, the *linkages* and resulting *outcomes*, leading to economic and social *impacts*.

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Indicators that describe the *actors* and *activities* are of great importance in the early stages of measurement, capturing who is doing what STI activities, where, how and why. As time passes and policy needs evolve, interest shifts to measures of *linkages*. These may include the flow of graduates to industries, the sources of funding, and the licensing of IP from government or universities.

Measures eventually begin to address the *outcomes* and *impacts* of STI. If outputs are the direct result of STI activities (number of patents granted, articles published, new products produced), then outcomes are the medium-term result of STI activities (more skilled employees, greater market share). These can typically be measured through administrative or survey data. Impacts, however, are the longer-term consequence of activities, linkages and outcomes. For the reasons discussed in the preceding section, these are more difficult to measure and are usually, but not always, addressed analytically. Some practical examples of the system follow.

- A small firm (*actor*) conducts R&D in telecommunications (*activity*), which requires a team of skilled employees and venture capital funds (*linkages*). The result is a new cellular telephone (*outcome*), which has an *impact* on the communication patterns of individuals and the organizational practices of business.
- Universities (*actors*) engage in innovation in biotechnology (*activity*) through collaborative partnerships with government (*linkages*). The result is a life-saving heart medication (*outcome*), leading to an improved quality of life for those who take it and changes in labour demand by the pharmaceutical industry (*impacts*).

7.4.2. A conceptual model

Figure 7.1 illustrates the relationships in the STI system. This model recognizes that actors generate, transmit and use STI knowledge by engaging in activities. Linkages represent the means by which STI knowledge is transferred between actors and through activities, leading to measurable outputs and intermediate outcomes. In turn, linkages, outputs and outcomes lead to a wide range of longer-term impacts.

While the model describes the flow of STI knowledge through the system, it also takes into account the complexities of existing indicators and the development of new ones. For example, measures of linkages and outcomes contribute to a better understanding of impacts; output indicators can be partial measures of impacts (Arundel 2006); and impacts can influence the generation, transmission and use of new STI knowledge, as the cycle begins again.

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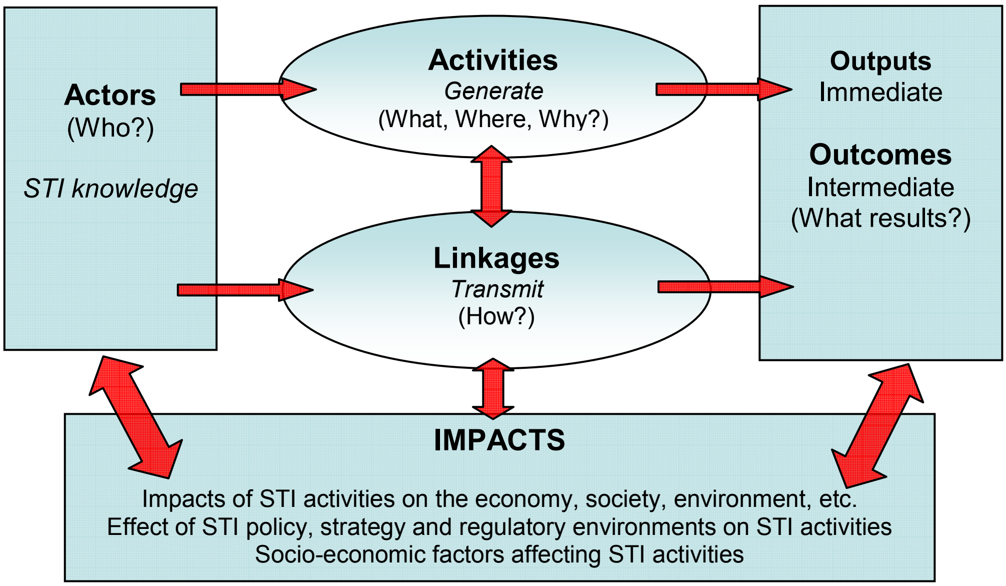
Figure 7.1. A conceptual model for STI indicators



Source: Adapted from Statistics Canada (1998a) and OECD (2005).

7.5. Existing measures

A number of initiatives are currently underway that use existing measures of STI to shed light on impacts. For example, linkages between the use of information and communication technology (ICT) and a number of social and economic outcomes, including literacy, income and time use, have already been made. The impacts of ICT on communication and spending patterns, as well as on people's work and leisure time, are being explored, and work is progressing on linking innovation to commercialization, and R&D investments to results.

7.5.1. Innovation, commercialization and IP

The *Oslo Manual* (OECD/Eurostat 2005) already contains advice on how to interpret the impacts of innovation. To date, national surveys have focused on factors that affect the bringing of the first copy of a product to market, with some indicators of the percentage of sales due to new or significantly improved products. Statistics Canada's Survey of Innovation 2005 (Statistics Canada 2006a) is based on the principles of the *Oslo Manual*, as well as on the approach adopted by the Community Innovation Survey (CIS). It includes detailed questions to elicit a better understanding

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of the nature of innovation and its commercialization at the firm level, including business success factors and obstacles, sources of information and impacts of innovation.

One of the more important research questions in this area relates to the relationship between innovation and firm performance. The characteristics of innovative and non-innovative firms, particularly in the Canadian service sector, have been examined with a view to gaining more information about this association. To obtain a better understanding of the impacts of innovation and technological change, the survey goes beyond the "core" questions, addressing the link between innovation and human resource capability, the flow of innovative goods and services (supply chain) and outsourcing, and the creation and loss of jobs.

In addition, a new "impact" module in the 2005 survey has improved understanding of the linkages and outcomes associated with innovation activity. Firms were asked to indicate the degree of importance of various impacts, such as increased range of goods or services, improved flexibility of production or service provision, increased plant productivity, increased market share, reduced environmental impacts, and improved health and safety.

If innovation is defined as the first commercial use of a new or significantly improved product or process, then commercialization can be seen as one aspect of the economic impacts of STI activities. Most questions in the early innovation surveys related only to the introduction of an innovation. The 2005 revisions to the *Oslo Manual* (OECD/Eurostat 2005) broadened the wording to include organizational structures and management practices, as well as innovation activities or projects and commercialization. These revisions have led to new indicators of innovation, which show how knowledge from different sources combines to add value to a firm, leading to impacts on business and people (Gault 2006).

Survey questions about innovation activities also address the introduction of innovations to the market and post-introduction commercialization. Others ask about barriers to the commercialization of innovation, and questions on sources of funding and support for commercialization are also included.

In a first step towards a better understanding of the economic impacts of STI activities, Statistics Canada is undertaking a set of feasibility studies, using **case studies**.

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- **Pre-commercialization activities in universities, government and the private sector.** What approaches are organizations using to optimize the commercialization potential of their research effort (*i.e.* activities ranging from directing research into "commercializable" areas to business planning and marketing potential technologies)?

- **Private-sector licensing (in and out).** What are the national and international sources of the technologies being used in the private sector? What is the value of publicly funded technology? What is the destination of the technology developed in Canada? What are the regional, sectoral and international destinations? This study will develop an approach to tracing licensing between sectors, countries and regions.

- **Private-sector IP management.** Are inventions being reported, patented and licensed? What is the propensity of Canadian companies to protect their IP and of managers to recognize the commercial potential of their inventions? Indicators similar to those in the public-sector IP management surveys will be developed.

- **The importance of management capacity.** What skills are required to obtain optimal benefits from technology – for example, recognition of market potential (vision); business and management skills (funding, organization, production); technological skills; legal skills (IP management)? Are businesses with access to these skills more likely to innovate, to commercialize, to be successful?

- **The relative contribution to sales of process innovation.** Surveys of innovation ask for the proportion of sales from new or significantly improved products. This study will attempt to determine the extent and nature of the contribution of new processes by reporting on their characteristics and their impact on products produced.

- **Commercialization of R&D and small R&D performers.** This study will develop *a)* an approach to tracing R&D effort to the marketplace; and *b)* an understanding of why many smaller R&D performers conduct R&D intermittently. An interviewer guide has been prepared (Statistics Canada 2006b), and a summary of interview findings released (Rosa and Rose 2007). Surveys will follow.

- **Commercialization of innovation.** What actions are taken to maximize the commercial benefits from innovation? What barriers remain to obtaining optimal benefits? To what extent are inventions being patented and licensed abroad? Questions on marketing activities are included in Statistics Canada's Survey of Innovation 2005; however, additional work will develop an approach to determining the contribution of com-

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mercialization activities to the proportion of sales from new or improved products.

One component of these studies, IP management, is already understood to some degree for the public sector. Statistics Canada has been conducting surveys in the higher-education sector and in federal departments since 1998 to determine how to maximize the benefits resulting from public-sector research. Indicators include IP management infrastructure and expenditures, number of patents held and commercialized, and licensing. One of the main insights gained from these surveys is that the direct returns from licensing income are very small compared to the original outlay of R&D. Total royalties for all universities in 2004 were about $56 million (Read 2006). The presumption is that the benefits to the economy of IP licences are many times that value. Furthermore, the benefits of *unlicensed* IP (*i.e.* published papers, consulting activities, know-how gained) are probably very large as well. One of the objectives of the commercialization studies is to determine the value to the public sector of IP transferred from the public sector to the private sector.

Bordt and Earl (2004) conducted a preliminary investigation into the benefits of public-sector IP to the private sector. About 4 120 firms reported that they licensed technologies from the public sector (institutes of higher education, government and hospitals). Over 4 400 reported that technology acquired from the public sector played a major role in the firm's success. The commercialization studies will develop means of asking these companies what the value is to them of the technology that has been transferred.

7.5.2. R&D

Canada's federal government is a major player in S&T, investing over $9 billion each year through direct support for businesses, universities and federal R&D, and related scientific activities (RSA) (Statistics Canada 2006c). Existing data-gathering efforts follow the guidelines of the *Frascati Manual* (OECD 2002) and focus primarily on S&T inputs – R&D expenditures by performing and funding sector, R&D personnel, socio-economic objectives of R&D, application of R&D, linkages between R&D performers and funders, and the number of full-time equivalents (FTEs) engaged in R&D. There is limited information about the results and outcomes of R&D investments.

Work led by Industry Canada's Innovation Policy Branch, in partnership with Statistics Canada and others, is underway to strengthen the linkages between R&D investments and outcomes for Canadians, as well as the current knowledge base on the impacts of federal S&T investments.

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Specifically, this work will build on information already collected on the socio-economic objectives of the R&D performed, as well as data on patents and royalties from federal laboratories and universities. The results indicators project will help to develop a more detailed picture of these investments, determine areas for improvement in federal support, and identify larger social and economic impacts of government expenditures on business R&D. A number of related projects are underway.

- **Current measures for federal government R&D activity.** Determine the current federal government results indicators for R&D expenditures.
- **Linkage of R&D expenditures to results indicators.** Use a sample of government R&D projects linking expenditures and results, and best practices to build a database for results indicators.
- **Commercialization feasibility studies.** Measure the value of, barriers to and impacts of commercialization activities.

7.5.3. Advanced technologies

The adoption and integration of advanced technologies into business may have important social and economic outcomes and impacts, which can be explored both qualitatively and quantitatively. Existing Statistics Canada programs measure the level of advanced technology diffusion across industries, as well as the actors, activities, linkages and outputs associated with technology diffusion.

7.5.3.1. Manufacturing technology

The impacts of advanced manufacturing technology (AMT) are being explored by linking AMT surveys to production surveys. To reduce the burden of and ensure consistency of response, the approach taken is to link the results of surveys that collect mostly qualitative data to the results of quantitative production surveys. These data linkages have demonstrated that manufacturing establishments using AMTs outperform those that do not (Baldwin, Diverty and Sabourin 1995; Baldwin and Sabourin 2001, 2004; Baldwin, Sabourin and Smith 2003). Moreover, advanced technology adoption in the manufacturing sector has been shown to lead to better jobs, and higher wages and salaries than non-adoption. Other impacts include gains in market share at the expense of non-adopters and growth in labour productivity.

Responses from surveys containing qualitative questions are also useful for understanding the outcomes and impacts of AMT adoption. For example, technology adoption may result in the need for more training and/or a shortage of skills to operate the technology. In turn, the actions taken by

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plants in response to advanced technology adoption will have additional impacts. Such issues were explored in the 1998 Survey of Advanced Technology in Canadian Manufacturing (Arundel and Sonntag 1999), in which information was collected on technology use, skill shortages and actions taken to deal with shortages, such as employee training. This type of information begins to address the cycle of STI indicators by tracking the activities, linkages and resulting outcomes.

Arundel and Sonntag (1999) found that skill shortages increased AMT investment shares (the percentage of total investment in machinery and equipment spent on AMTs in the previous three years) and the probability of adopting a new type of AMT. Although skill shortages increase costs through training, and higher wages and salaries, they do not prevent plants from acquiring new AMTs.

Work is already underway on the 2007 Survey of Advanced Technology for Manufacturing and Logging. The survey will include detailed questions about advanced technology adoption and planned use, as well as results and outcomes. In particular, respondents will be asked to rate the impact of a number of effects following the adoption of advanced technology, including: reduced labour requirements per unit of output (productivity); reduced time to market, improvement in product quality (product improvement); increased flexibility, customization, specialization or skill requirements (business unit organization); reduced energy costs (business unit efficiencies); increased profitability, opening new export markets (market performance); and reduction of environmental impacts. The new survey will also address linkages between innovation and technology adoption.

7.5.3.2. Biotechnology

Canada has pioneered a number of important concepts and data collection initiatives related to biotechnology. Beginning with a pilot survey in 1997, Statistics Canada has conducted the Biotechnology Use and Development Survey (Statistics Canada 2007a) in alternating years. The survey was designed to begin to measure direct outputs and outcomes, including indicators of business practices and revenues, counts of products on the market, employment in biotechnology activities, expenditures on R&D, IP management, use of tax incentives, costs of regulatory compliance and sources of funds. Existing social outcome indicators for biotechnology are related to human resources – employment, unfilled job openings, recruiting from abroad, spinoffs from public organizations, impact on employment of contracting activities, and collaborative arrangements. Some of these concepts can also be extended to the previously mentioned work on commercialization (*i.e.* the granting and obtaining of IP rights).

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Statistics Canada conducted the world's first Bioproducts Development Survey in 2004 (Statistics Canada 2005a), which aimed to capture the development and production of these alternative products in Canada. This information, albeit limited, offers the potential to begin an assessment of the impacts of bioproducts development; existing economic measures include rates of use by firms and values of sales from bioproducts (relative to traditional products). Similarly, the Functional Foods and Nutraceuticals Survey (Statistics Canada 2003) provides financial measures of firms engaged in the production or development of these products, including revenues, exports and R&D, both as a total for the firm and as they relate to functional foods and nutraceuticals. The survey also addresses business practices, raising capital, IP and human resources. Some analysis has been done to examine the impacts of regulation on functional food and nutraceutical product activities (Tebbens 2005). This study reported that about 40% of firms would be willing to conduct research to support health claims related to functional foods and nutraceuticals if labeling regulations were changed. Firms were also asked about the perceived impact of changes to regulations on domestic sales, export sales, and ability to compete with global competitors.

7.5.3.3. ICT

Much attention has been directed to ICT indicators, in large part as a result of the World Summit on the Information Society (WSIS), the first phase of which was held in Geneva in 2003 and the second in Tunis in 2005. A number of global initiatives have been completed, including the identification of core indicators for the information society, the completion of the OECD *Guide to Measuring the Information Society* (2005), and the building of capacity to improve ICT indicators globally and in developing countries. Again, most of the existing indicators capture infrastructure, access and use, as well as some linkages and early outcomes.

Understanding ICT impacts is important, not only for guiding policy, but also for making the case for ICT diffusion in developing countries. The link between ICTs and development has been the driving force behind much of the international activity, including the WSIS. Interest in issues such as economic marginalization and social exclusion has led to closer investigations of the "digital divide" (Sciadas 2002; Orbicom 2003, 2005). This work represents a huge step forward in the development of a framework for measuring the divide, monitoring its evolution across a great number of countries, and examining the strengths and weaknesses of country-specific ICT policies.

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Although relatively little has been done to assess the impacts of ICT use by households and individuals, it is accepted that changes are occurring in the way people work, communicate and spend their time. These changes will lead to impacts on the economy and society, but such impacts are not easily measured through official statistics and surveys. Rather, analytical tools are needed to identify the linkages and contribute to the understanding of these impacts.

- **Surveys of Internet use**, beginning with the 1997 Household Internet Use Survey (HIUS) (Statistics Canada 1998b), provided the first indicators of Internet penetration among households. Over time, and as use of the Internet has become more widespread, analytical work has shifted to exploring the linkages and outcomes of ICT. This shift prompted a redesign of the HIUS, leading to the release of the first Canadian Internet Use Survey (CIUS) in 2005 (Statistics Canada 2006d). Now based on individuals, the CIUS allows for a broader analytical approach and, for the first time, uses an internationally comparable dataset to help situate Internet use in Canada in relation to Internet activity in other countries. The availability of data on how the Internet is used and experienced directly by individuals places analysts in a better position to begin to address outcomes.

- **Early outcomes of Internet use** were assessed in the 2000 General Social Survey Cycle 14: Access to and Use of Information and Communication Technology (Statistics Canada 2001). The survey used a direct approach to ask respondents whether their use of the Internet had changed the amount of time they devoted to other activities, such as watching television and spending time with family (Dryburgh 2001).

- **Relationships between literacy skills and ICT use** were explored in a study based on data from the International Adult Literacy and Life Skills Survey (IALS) (Statistics Canada 2005b). The study found that, as literacy skill levels rose, so did other factors, such as the perceived usefulness of computers, diversity and intensity of Internet use, and use of computers for task-oriented purposes. This occurred even when other factors with an impact on computer use, such as age, income and education level, were taken into account. **Outcomes of ICT use** were also investigated: for example, it was found that people who used computers and had higher literacy rates were far more likely to have higher incomes (Sciadas, Clermont and Veenhof 2005).

- A more recent study of **how Internet users spend their time** focused on different economic, social and recreational behaviours among Internet users and non-users (Veenhof 2006). **Changes in communication and spending patterns induced by ICTs** have also been examined (Sciadas

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2006). This type of work enhances understanding of the social outcomes associated with ICT use.

Internationally, much has been done with respect to exploring the economic impacts of ICTs, using macro-data, industry data and micro-data. For example, evidence from firm-level studies suggests that the use of ICT has positive impacts on firm performance and productivity (OECD 2004; Pilat 2005). However, it is important to note that these impacts occur in conjunction with other changes and investments in a firm – for example, improved skills and organizational changes. At the aggregate level, studies have shown that investment in ICT contributes to capital deepening and growth (OECD 2005). An "impacts workshop" at the 2006 WPIIS meetings further highlighted country experiences and analyses in this area (Clayton 2006; Pilat 2006). Following are summaries of some Canadian initiatives.

- A study of the **changing patterns of capital formation and sources of economic growth for Canadian business** began to address the impacts of technological progress and the accumulation of ICT assets on the Canadian business sector. The data show that increases in capital and labour continue to be important contributors to output growth. Multi-factor productivity is also an important source of growth in output (Harchaoui *et al.* 2001).
- **The Survey of Electronic Commerce and Technology (SECT)** (Statistics Canada 2007b) has provided baseline data for ICT adoption by Canadian businesses since 2000. SECT was a "world-first" for a statistical agency in terms of cross-economy measures of e-commerce. Survey questions also address the perceived benefits of and barriers to buying and selling on-line, in an effort to understand linkages and associated outcomes and impacts, although these measures are less objective than empirical measurement techniques.
- **The newly developed researcher database facilitates the use of SECT micro-data for research and analysis** under Statistics Canada's Facilitated Access Program. Recent work involved researchers from the University of Waterloo, who used the database to focus on factors influencing the transition of Canadian firms from one stage of e-business to another. Using the Technology, Organizations and Environment (TOE) framework, the researchers were able to follow individual firms over a three-year period. Preliminary results from the study suggested that firms both progress and regress through the stages of e-business. While a smaller proportion of large firms regressed, very few firms of any size made the jump from having no Web site at all to conducting e-commerce sales on a Web site during the period of study (Klassen and Carnaghan 2006).

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7.6. New approaches

Although work on understanding impacts has been advancing, there is still much to be done. Studies aimed at gaining a better understanding of STI impacts must take into account the fact that, although many impact indicators are comparable across applications (improved health and well-being, increased market share and lower production costs, changing social behaviours), others are application-specific – for example, the annual reduction in greenhouse gases from biofuels (Arundel 2006). Impacts should be assessed with a sense of their relevance to the STI activity concerned. Depending on that activity, they may take longer to observe, which makes them even more difficult to identify. In such cases, one could begin to identify the *potential* outcomes and impacts of the activities, in an attempt to trace them back through measures of linkages. These limitations mean that different approaches to understanding impacts may be required for different STI activities.

- Statistics Canada's **2007 Survey of Commercialization** will provide further insight into the benefits of public-sector technology transferred to the private sector, the proportion of R&D that is commercialized, and the contribution of revenues from process innovation. Research in the area of IP management in the public sector and results from a new survey on business incubators will give rise to alternative approaches to and measures of impacts.

- There are two types of **outcomes for products and processes developed through biotechnology activities**: those that are substitutions for or improvements of existing products or processes; and those that are entirely novel or radical. The impacts from these outcomes could be assessed in different ways. Assessment of the impacts of substitution, for example, could address the reasons for it – less expensive, more reliable/less risk.

- **The public sector is a major source of new knowledge, which leads to market activities through the commercialization of IP and the creation of spinoffs**. The public sector is also a tester and early adopter of new technology, helping to influence the diffusion and adoption of technology and practices as they become more generally accepted. To advance the work of STI outcomes and impacts, it is important to continue and improve measurement activities for the public sector.

- Work has also begun on **understanding the role of organizational practices, such as knowledge management, in firms' productivity and survival**. This type of organizational innovation further highlights the linkages between knowledge generation, transfer and use within the

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firm and the economy. Developing a better approach to understanding organizational innovation – especially its impacts – should be a priority.

- Studies of the impacts of ICT use have typically relied on direct assessment through respondent perceptions. As ICT penetration rates have begun to reach saturation levels in some countries, there is a need for **new insights into ICT linkages and outcomes**, whether through time-use studies, longitudinal studies or other instruments, such as micro-simulation. One approach is to examine the expected outcomes associated with ICT retrospectively to assess whether they have occurred. For example, Sciadas (2006) used statistical information to demonstrate that the "paperless" society, the reduction in physical mail and the end of traditional retail have – so far – not materialized. Related questions were also addressed in the study: How and to what extent has the availability of on-line shopping changed the shopping behaviour of Canadians? How has the adoption of digital technologies affected individual communication patterns?

- Statistics Canada's Facilitated Access Program provides researchers with **access to micro-data**, subject to project approval and user fees. This program contributes to the basic framework of STI activities – the generation, transmission and use of STI knowledge. Participating surveys include the 1998 Survey of Advanced Technology in Canadian Manufacturing, the Survey of Innovation, the Biotechnology Use and Development Survey and SECT. The use of micro-data as a tool to assess impacts should be encouraged. Linking activity surveys with financial or administrative sources would also enhance understanding of impacts.

7.7. Main recommendations

The proposed recommendations offer the international community opportunities for extending work on impacts beyond what has been possible for individual countries. The development of new indicators and new approaches for understanding impacts should be a collaborative effort, beginning with an agreed framework for indicators. This will ensure internationally comparable measures and a recognized set of guidelines, which can be used to steer STI policy for the next decade.

It is therefore recommended that experts, policy makers, national statistical offices and international organizations:

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- Coordinate their activities to develop an agreed conceptual framework for STI impact indicators;
- Coordinate the development of guidelines, indicators and approaches for assessing STI impacts, recognizing the benefits of international comparability, but ensuring that indicators meet national priorities for policy making and planning; examples of indicators that could be developed include:

Innovation, commercialization and IP

- The success rate of commercialization (measured as a ratio of expenditure on R&D resulting in commercialization – licences, patents, inventions and spinoff companies – to total expenditure on R&D).
- The proportion of patents (government, higher-education and private-sector) that has been assigned or otherwise commercialized.
- The proportion of sales due to new or significantly improved processes, marketing innovations and organizational change.
- The value and utility of products and processes perceived by consumers.
- Measures of work culture and structures.
- A conceptual framework linking innovation, commercialization and productivity (as recommended in the *Oslo Manual* (OECD/Eurostat. 2005, para. 413); see Bordt *et al.* 2005).
- Definitions of international core concepts and model questionnaires for IP management in public and private sectors.

Biotechnology, bioproducts, and functional foods and neutraceuticals

- The perceived impacts of products/technologies, *i.e.* screening technology for early diagnosis.
- The purpose of products/technologies (health, environment, agriculture), *i.e.* to reduce the use of pesticides.

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ICT

- Measures of social outcomes/behaviours – health and well-being, employment, spending patterns, time use, communication patterns, social networks.
- Measures of ICT divides – rural-urban, gender, age, education, income – to determine how more intense use of ICT and/or type of Internet use affect the gap between ICT "haves" and "have-nots".
- Measures of economic outcomes – the impact of broadband, e-commerce efficiency, organization of work, firm performance.
- Measures of ICT skills (or digital literacy) – the ability to navigate, retrieve, and interpret and apply information using a variety of methods and formats.
- Continuation of capacity building and information exchange through international working groups, such as the WPIIS Expert Group on ICT Impacts.
- Further develop analytical techniques and tools to trace pathways and identify sequences of events.
- Build on linkages and associations to gain a better understanding of decision-making, changes in behaviours, outcomes and impacts by:
    - Making use of different types of data (micro-data, longitudinal data);
    - Making use of different analytical approaches (case studies, data linkage);
    - Making use of different analytical techniques (econometric modeling, microeconomic simulation modeling); and
    - Focusing on attempts to understand individual businesses by linking financial data with firm activities to follow firms over time (*i.e.* survival and growth studies).

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Annex A

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Acronyms and Abbreviations

AIDC	Automotive Industry Development Centre
AIDS	Acquired Immune Deficiency Syndrome
AMTS	Advanced Manufacturing Technology Strategy
Armscor	Armaments Corporation of South Africa
ASGISA	Accelerated and Shared Growth Initiative for South Africa
ASSAf	Academy of Science of South Africa
BEE	Black economic empowerment
BERD	Business Enterprise Expenditure on Research and Development
BPO	Business process outsourcing
BRIC	Biotechnology Regional Innovation Centre
CeSTII	Centre for Science and Technology and Innovation Indicators
CHE	Council on Higher Education
CIDAUT	Research and Development Centre in Transport and Energy, Spain
CIS	Community Innovation Survey
CRI	Crown Research Institute, New Zealand
CSIR	Council for Scientific and Industrial Research, South Africa
CSP	Customised Sector Programme (a DTI initiative)
DACST	Department of Arts, Culture, Science and Technology (now the DST)
DEAT	Department of Environmental Affairs and Tourism
DEEM	Design, engineering, entrepreneurial and management
DEET	Department of Environmental Affairs and Tourism
DESA	Development Bank of Southern Africa
DoE	Department of Education
DST	Department of Science and Technology
DTI	Department of Trade and Industry
Eskom	Electricity Supply Commission
EU	European Union

FDI	Foreign direct investment
FEST	Foundation for Education, Science and Technology
FFG	Austrian Research Promotion Agency
FRAM	Norwegian entrepreneurship training programme
FTE	Full-time equivalent
GDP	Gross domestic product
GEM	Global Enterprise Monitor
GEAR	Growth, Employment and Redistribution
GERD	Gross domestic expenditure on research and development
GTS	Advanced Technology Group, Denmark. A network of research institutes.
HBT	Historically black technikon
HBU	Historically black university
HEI	Higher education institution
HERD	Higher Education Expenditure on Research and Development
HIV	Human immunodeficiency virus
HSRC	Human Science Research Council
HWT	Historically white technikon
HWU	Historically white university
ICT	Information and communications technology
IDC	Industrial Development Corporation
IKS	Indigenous knowledge system
IMEC	Interuniversity Microelectronics Centre, Leuven, Belgium
IMS	Integrated Manufacturing Strategy
IP	Intellectual property
ISI	Institute for Scientific Information, Philadelphia
IT	Information technology
IWT	Institute for the Promotion of Innovation by Science and Technology in Flanders, Belgium
JIPSA	Joint Initiative on Priority Skills Acquisition
KIBS	Knowledge-intensive business services

MEC	Minerals-energy complex
Mintek	Council for Mineral Technologies
MiTech	Missions in Technology
MPE	Multotec Process Equipment
MNC	Multinational Corporation
MRC	Medical Research Council
MSDS	Metals Sector Development Strategy
NACI	National Advisory Council on Innovation
NCTC	National Casting Technology Centre
NECSA	Nuclear Energy Council of South Africa
NFTCC	National Fibre, Textile and Clothing Centre
NRF	National Research Foundation
NSTF	National Science and Technology Foundation
NTCCD	National Technology Transfer Center
PBMR	Pebble Bed Modular Reactor
PPP	Purchasing power parity
PRI	Public research institute
R&D	Research and development
RANNIS	The Icelandic Centre for Research
RCN	Research Council of Norway
RDP	Reconstruction and Development Programme
RISA	Research and Innovation Support and Advancement division of NRF
S&T	Science and technology
SAASTA	South African Agency for Science and Technology
SAAVI	South Africa AIDS Vaccine Initiative
SADC	South Africa Development Community
SEDA	Small Enterprise Development Agency
SETA	Sector Education and Training Authorities

SINTEF	The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology
SME	Small, medium and micro enterprise
SP	SP Technical Research Institute of Sweden (formerly the State Testing Authority)
SPII	Support Programme for Industrial Innovation
STI	Science, technology and innovation
STU	The Swedish National Board for Technological development
TAP	Technology Advancement Programme
TEKES	Finnish Funding Agency foe Technology and Innovation
TFP	Total factor productivity
THRIP	Technology and Human Resources for Industry Programme
TNO	Netherlands Organisation for Applied Scientific Research
UNISA	University of South Africa
VAT	Value-added tax
VINNOVA	Swedish Governmental Agency for Innovation Systems
VTT	VTT Technical Research Centre of Finland

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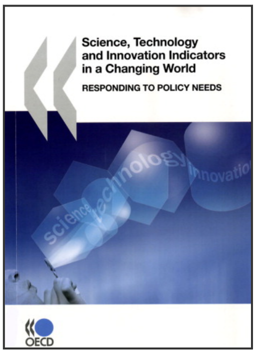

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