Towards understanding impacts of science, technology and innovation activities

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1. Context

Science, technology and innovation (STI) activities have been one of the driving forces of economic and social change for centuries. 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 an increased capacity to generate, transmit and use STI knowledge.

Despite their importance, much of the existing information about STI activities 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 in order to track who is doing what, where, how and why. However they are not as 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 paper presents Canadian initiatives towards understanding the social and economic impacts of STI activities. In particular, it discusses measures currently used by Statistics Canada and others to describe STI activities, and offers new approaches towards 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.

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).

2.1 Developing indicators

In order 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 Organization 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 & development (R&D); innovation; intellectual property (IP) and its commercialization; and technology adoption and diffusion. Work began with programs intended to gain insights into inputs and outputs of STI activities, which then led to a broader focus on STI linkages and outcomes (for example, uses of ICTs, determinants of innovation, new technology adoption, and business practices). Now, there is 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 is essential if work on STI outcomes and impacts is to continue to advance.

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 reality 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 more difficult to identify and cannot be easily 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, the society and more; and they can affect the environment surrounding STI activities, resulting from changes in STI policy or strategy (Statistics Canada 1998).

Finally, impacts cannot be measured in the same way as activities. Impacts are better understood through a combination of surveys and analytical techniques, rather than 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 2006; Sciadas et al. 2005; Veenhof 2006) and micro-economic 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.

4. A systematic view of STI indicators

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

4.1 A framework for STI indicators

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 statistical information system for science and technology shortly after the first Blue Sky conference (Statistics Canada 1998). The system is comprised of a set of *actors* engaged in *activities*, the *linkages* and resulting *outcomes*, leading to economic and social *impacts*.

Indicators describing the *actors* and *activities* are of great importance in the early stages of measurement. They capture the 'who', 'what', 'where', 'how' and 'why' of STI activities. 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 intellectual property from government or universities.

Measures eventually begin to address *outcomes* and *impacts* of STI. If outputs are the direct results of STI activities – number of patents granted, articles published, new products – then outcomes are the medium term results of STI activities – more skilled employees or greater market share. These can typically be measured through administrative or survey data. Impacts, however, refer to the longer term consequences of activities, linkages and outcomes. For obvious reasons, these questions are more difficult to measure and are usually, but not always, addressed analytically. Some practical examples of the system follow below:

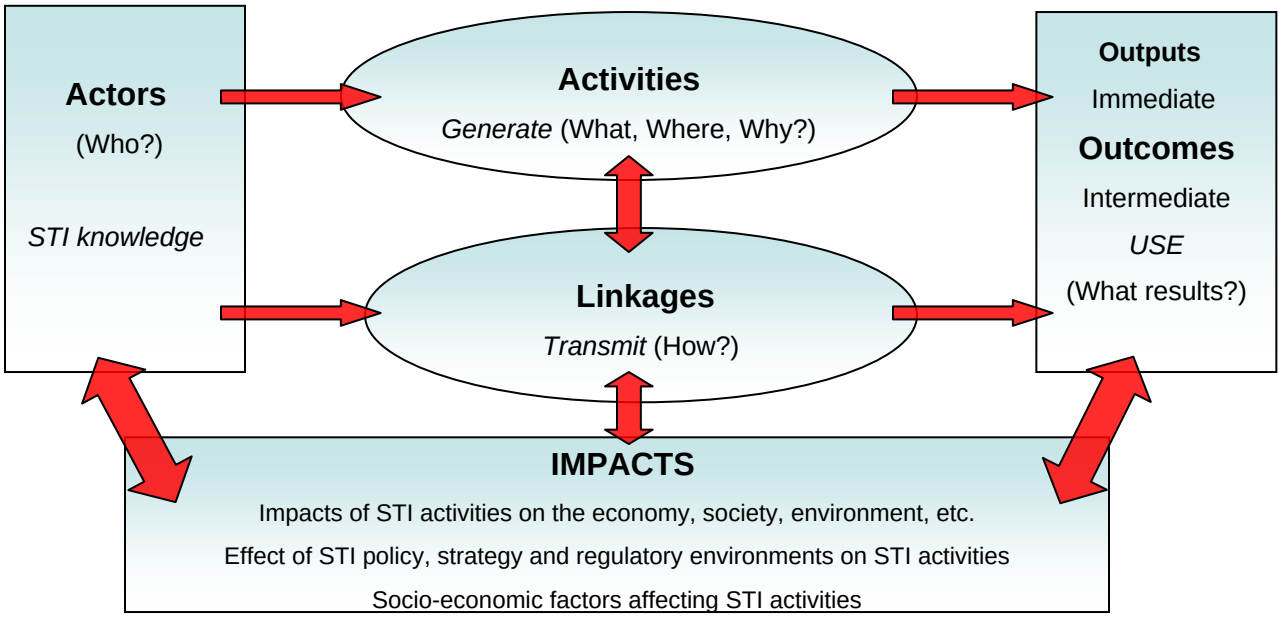
- A small firm (actor) conducts R&D in telecommunications (activity), which requires a team of skilled employees and venture capital funds (linkages). The result is a new cellular telephone (outcome), which has an impact on the communication patterns of individuals and the organizational practices of 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 the medication and changes in labour demand by the pharmaceutical industry (impacts).

4.2 A conceptual model

Figure 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.

Figure 1. A conceptual model for STI indicators



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

5. Existing measures

A number of initiatives are currently underway which use existing measures of STI to shed light on impacts. For example, linkages between the use of 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 R&D investments to results, and innovation to commercialization.

5.1 Innovation, commercialization and intellectual property

The Oslo Manual (2005) already contains advice on how to interpret the impacts of innovation. To date, national surveys have focused on factors that affect putting the first copy of the product on the shelf, with some indicators of the percentage of sales due to new and significantly improved products. Statistics Canada's Survey of Innovation (2005) is based on the principles of the Oslo Manual, as well as the approach adopted by the Community of Innovation Surveys (CIS). The survey includes detailed questions to better understand 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. In order to better understand this association, the characteristics of innovative and non-innovative firms have been examined, particularly in the Canadian services sector. In order to better understand 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 our understanding of the linkages and outcomes associated with innovative activity. Firms were asked to report 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 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. Following the 2005 revisions to the Oslo Manual, the wording was broadened 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 the firm, leading to impacts on business and people (Gault 2004).

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

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

- **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. 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 for Canadian companies to protect their IP and of managers to recognize the commercial potential of their inventions? Similar indicators to the public sector IP management surveys will be developed.
- **The importance of management capacity:** What skills are required to obtain optimal benefits from technology, e.g., recognition of market potential (vision); business and management skills (funding, organization, production); technological skills (making it work); legal (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 and significantly improved products but not on the extent and nature of the contribution of new processes.
- **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.

- **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 on the Canadian Survey of Innovation 2005; however additional work will develop an approach to determining the contribution of commercialization activities to the proportion of sales from new and 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 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 $56M (Read 2006). The presumption is that the benefits to the economy of the IP licenses are many times that value. Furthermore, the benefits of *unlicensed* IP (i.e. published papers, consulting activities, know-how gained) are likely very large as well. One of the objectives of the commercialization work is to determine the value to the public sector of IP transferred from the public sector.

Earl and Bordt (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 (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.

5.2 Research and development (R&D)

The federal government is a major player in science and technology, investing over nine billion dollars each year through direct support for businesses, universities and federal R&D, and related scientific activities (RSA) (Statistics Canada 2006). Existing data gathering efforts follow the Frascati Manual guidelines (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, the application of R&D, linkages between R&D performers and funders and the number of FTE 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 impacts of federal S&T investments. Specifically, this work will build on information already collected on the socio-economic objectives for the R&D performed, as well as data on patents and royalties from federal labs and universities. The results indicators project will help develop a more detailed picture of these investments, identify areas for improvement in federal support, and identify larger social and economic impacts of government expenditures on business R&D. A number of projects are underway, including:

- **Current measures for federal government R&D activity**: What are current federal government results indicators for R&D expenditures?
- **Linking R&D expenditures to results indicators:** Use sample of government R&D projects linking expenditures and results, and best practices to build a database for results indicators.

- **Commercialization feasibility studies:** measure value of, barriers to and impacts of commercialization activities.

5.3 Advanced technology

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.

5.3.1 Manufacturing technology

The impacts of advanced manufacturing technology (AMT) are being explored by linking AMT surveys to production surveys. In order to reduce response burden and to ensure consistent responses, the approach taken is to link results of surveys that collect mostly qualitative data to results of quantitative production surveys. These data linkages have demonstrated that manufacturing establishments using advanced manufacturing technologies outperform those that do not (Baldwin, Diverty and Sabourin 1995; Baldwin and Sabourin 2001, 2004; Baldwin et al. 2003). Moreover, advanced technology adoption in the manufacturing sector has been shown to lead to better jobs and higher salaries/wages 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 in understanding outcomes and impacts of manufacturing technology 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 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, where information was collected on technology use, skills 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 following the activities, linkages and resulting outcomes.

Arundel and Sonntag (1999) found that skill shortages increased AMT investment shares (percentage of total investment in machinery and equipment in the previous three years that was spent on AMTs) 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 for the 2006 Survey of Advanced Technology for manufacturing and logging. It includes 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, among others, reduced labour requirements per unit of output (productivity); reduced time to markets, 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); reduction of environmental impacts. The new survey will also address linkages between innovation and technology adoption.

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 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, intellectual property 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, spin-offs 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., granting and obtaining IP rights).

Statistics Canada conducted the world's first Bioproducts Development Survey in 2004, which aimed to capture the development and production of these alternative products in Canada. This information, albeit limited, offers the potential to begin to assess the impacts of bioproduct 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 provides financial measures of firms engaged in 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). The study reported that about 40% of firms would be willing to conduct research to support health claims related to functional food 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.

5.3.3 Information and communications technology (ICT)

Much attention has been directed to ICT indicators, due in large part to the *World Summits on the Information Society* (WSIS, Geneva 2003 and Tunis 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 to make 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 marginalisation 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.

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; however such

impacts are not easily measured through official statistics and surveys. Rather analytical tools are needed to make the linkages towards understanding impacts:

- **Surveys of Internet use**, beginning with the 1997 Household Internet Use Survey (HIUS) 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 first release of the 2005 Canadian Internet Use Survey (CIUS). Now based on individuals, the CIUS allows for a broader analytical approach, and for the first time, uses an internationally-comparable data set to help situate Internet use in Canada with respect 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. The survey used a direct approach to ask respondents whether their use of the Internet had changed the 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).The study found that as literacy skill levels rose, other factors also rose, 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 having an impact on computer use were taken into account, such as age, income and education levels. **Outcomes of ICT use** were also investigated – people who used computers and had higher literacy rates, were far more likely to have higher incomes (Sciadas et al. 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). This type of work enhances our understanding of the social outcomes associated with ICT use.

Internationally, much has been done with respect to exploring the economic impacts of ICTs, using both 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 the 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). Some Canadian initiatives are summarized below:

- A study of the **changing patterns of capital formation and sources of economic growth for Canadian business** began to address 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. Multifactor productivity is also an important source of growth in output (Harchaoui et al. 2001).

- **The Survey of Electronic Commerce and Technology (SECT)** 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. Questions also address the perceived benefits and barriers to buying and selling on-line, in an effort to begin to understand linkages and associated outcomes and impacts, albeit 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 large firms had a smaller proportion of firms regressing, very few firms of any size made the jump from no web site at all to the stage of conducting e-commerce sales over a website during the period of study (Klassen et al. 2006).

6. New approaches

Although work on understanding impacts has been advancing, there is still much to do. 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 bio-fuels (Arundel 2006). Impacts should be assessed with a sense of relevance to the STI activity. In addition, impacts may take longer to observe depending on the STI activity, which makes them even more difficult to identify. In this case, one could begin to identify *potential* outcomes and impacts of STI activities, in an attempt to trace them back through measures of linkages. These limitations mean that different approaches towards understanding impacts may be required for different 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 and measures of impacts.
- There are two types of **outcomes for products and processes developed through biotechnology activities**; those that are substitutions or improvements of existing products or processes and those that are entirely novel or radical. Impacts from these outcomes could be assessed in different ways. Substitution impacts, for example, could address the reasons for substitution – 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 spin-offs.** The public sector is also a tester and early adopter of new technology, helping to influence the future diffusion and adoption of technology and practices as they become more generally accepted. In order 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, on firms' productivity and survival.** This type of organizational innovation further highlights the linkages between knowledge generation, transfer and use within the 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. For example, how and to what extent has the availability of online shopping changed the shopping behaviour of Canadians? How has adoption of digital technologies affected individual communications patterns? Research in these areas is already underway (Sciadas forthcoming).
- 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 Survey of Advanced Technology in Canadian Manufacturing (1998), the Survey of Innovation, Biotechnology Use and Development Survey, and the Survey of Electronic Commerce and Technology. The use of micro-data should be encouraged as a tool to assess impacts. Linking activity surveys with financial or administrative sources would also enhance our understanding of impacts.

7. Main recommendations and opportunities

The proposed recommendations are opportunities for the international community to extend 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 of indicators. This will ensure internationally comparable measures and a recognized set of guidelines, which can be used to guide science, technology and innovation policy for the next decade.

- Coordinate activities among experts, policy makers, national statistical offices and international organizations to develop an agreed conceptual framework for STI impact indicators.
- Coordinate the development of guidelines, indicators, approaches for assessing STI impacts. Recognize benefits of international comparability, but ensure that indicators meets national priorities for policy-making and planning:

Innovation, commercialization and IP

- proportion of R&D (government, higher education and private sector) that is commercialized
- proportion of patents (government, higher education and private sector) that have been assigned or otherwise commercialized
- proportion of sales due to new and significantly improved processes, marketing innovations and organizational change.
- perceived value and utility of products, processes by consumers
- measures of work culture and structures

- develop conceptual framework linking innovation, commercialization and productivity (as recommended in the Oslo Manual, para. 413)
- define international core concepts and model questionnaires for IP management in public and private sectors

Biotechnology, bioproducts and functional foods and neutraceuticals

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

ICTs

- measures of social outcomes/behaviours – health and well-being, employment, spending patterns, time-use, communications patterns, social networks
- measures of ICT divides – rural-urban, gender, age, education, income – how does more intense use of ICT and/or type of Internet use affect gap between ICT 'haves' and 'have-nots'?
- measures of economic outcomes – impact of broadband, e-commerce efficiency, organization of work, firm performance
- measures of ICT skills (or digital literacy): ability to navigate, retrieve, and interpret and apply information using a variety of methods and in a variety of formats.
- continue to build capacity and exchange information through international working groups, such as WPIIS expert group on ICT impacts

- Further develop analytical techniques and tools to trace pathways and identify sequence of events. Build on linkages and associations to better understand decision-making, changes in behaviours, outcomes and impacts:
    - make use of different types of data: micro-data, longitudinal data;
    - make use of different analytical approaches: case studies, data linkage;
    - make use of different analytical techniques: econometric modeling, micro-economic simulation modeling.
    - focus on understanding individual businesses – link financial data with firm activities to follow firms over time (i.e. survival and growth studies)

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