Innovation Impacts: Measurement and Assessment

The Expert Panel on the Socio-economic Impacts of Innovation Investments

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

INNOVATION IMPACTS: MEASUREMENT AND ASSESSMENT

The Expert Panel on the Socio-economic Impacts of Innovation Investments

THE COUNCIL OF CANADIAN ACADEMIES
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The Council also recognizes the important contribution of **William A.S. (Bill) Buxton,** Principal Researcher, Microsoft Research (Toronto, ON) to this assessment.

Message from the Chair

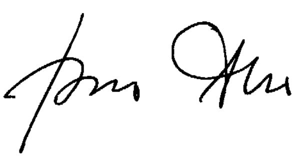
Throughout human history, innovation has been the driving force behind material and social progress. Today, economic and social well-being is perhaps even more intimately tied to innovation — the competitiveness of the business sector and the efficacy of the public sector depend on it. To ensure continued prosperity, governments must commit to innovation as a cornerstone of long-term public policies, creating the conditions and making the investments that are most likely to spur innovation. Effectively enhancing innovation requires governments to have access to reliable measurements of the impact of their investments.

To address this challenge in the Ontario context, the Expert Panel on the Socio-economic Impacts of Innovation Investments was formed. Building on its considerable expertise — as innovators, policy-makers, and measurement experts — the Panel went beyond existing practices around the world and those suggested in the academic literature. Through many deliberations, the Panel developed a pragmatic framework to measure innovation impacts and organize innovation policy thinking. I am confident this report will be an important tool for the Ontario government, and others, in formulating polices and deciding how to best support innovation.

The Panel benefitted greatly from expert witness presentations on best practices in measuring innovation impacts. I would like to thank Kathryn Graham, John Helliwell, Azam Khan, Anita McGahan, Pierre Mohnen, Peter Nicholson, and Steven Young for their authoritative and thought-provoking presentations.

I am very appreciative of the strong commitment, both of time and energy, of my fellow Panel members. Their collective wisdom and insights have resulted in a high-quality and extremely useful report.

Finally, the Panel and I are sincerely grateful to Council staff for their excellent support and help in bringing our ideas to fruition.



Esko Aho, Chair
The Expert Panel on the Socio-economic Impacts of Innovation Investments

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Report Review

This report was reviewed in draft form by the individuals listed below — a group of reviewers selected by the Council of Canadian Academies for their diverse perspectives, areas of expertise, and broad representation of academic, industrial, policy, and non-governmental organizations.

The reviewers assessed the objectivity and quality of the report. Their submissions — which will remain confidential — were considered in full by the Panel, and many of their suggestions were incorporated into the report. They were not asked to endorse the conclusions, nor did they see the final draft of the report before its release. Responsibility for the final content of this report rests entirely with the authoring Panel and the Council.

The Council wishes to thank the following individuals for their review of this report:

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The report review procedure was monitored on behalf of the Council's Board of Governors and Scientific Advisory Committee by **Murray S. Campbell**, Senior Manager, Business Analytics Research, IBM T.J. Watson Research Center. The role of the report review monitor is to ensure that the panel gives full and fair consideration to the submissions of the report reviewers. The Board of the Council authorizes public release of an expert panel report only after the report review monitor confirms that the Council's report review requirements have been satisfied. The Council thanks Dr. Campbell for his diligent contribution as review monitor.

Elizabeth Dowdeswell, O.C., President & CEO
Council of Canadian Academies

Executive Summary

Innovation is the *sine qua non* of economic and social progress. It is the predominant source of the new or improved products, processes, and methods of marketing and organization that drive the competitiveness of our business sector; generate the income that sustains our standard of living; alter the way we interact with each other and the natural world; and solve (and sometimes create) the technical and social problems we face. The key challenges for most economies — intensifying global competition in product markets, increasing demand for energy and other natural resources, and aging of the workforce — render economic competitiveness transient and easily eroded, potentially compromising the wealth of nations that fail to combat them. In addition, the growing pressure of complex, global challenges, such as climate change and financial system stability, suggests that harnessing the innovative capacity of humanity is more critical than ever before.

Long recognizing the importance of innovation, the Government of Ontario has signalled its clear commitment to it as the centrepiece of economic policy. This commitment is reflected in the establishment of the Ontario Ministry of Research and Innovation (MRI), the development of the Ontario Innovation Agenda, and a varied and generous set of innovation investments. In July 2011, MRI posed the following question to the Council of Canadian Academies (the Council):

> *How can the actual and potential outcomes and impacts of Ontario government spending on innovation and scientific activities be measured, including but not limited to the effects on GDP in Ontario, generation and transfer of knowledge; creation of new ventures; and access to seed, development and growth capital?*

In response, the Council appointed a panel of Canadian and international experts (The Expert Panel on the Socio-economic Impacts of Innovation Investments) from the academic, business, and public sectors. To address the charge, and its three sub-questions, the Panel catalogued the portfolio of Ontario innovation investments, conducted an extensive academic and public policy literature review of leading-edge measurement methodologies, and explored the best international practices in impact assessment. Then, drawing on its collective understanding of innovation and experience in impact measurement, the Panel developed a new conceptual framework for understanding innovation measurement and assessment.

PROGRAM IMPACT MEASUREMENT

Governments are not only faced with competing demands for public funds, but also with increased pressure to demonstrate value-for-money. With a surfeit of public spending priorities, public investments of any kind, including innovation investments, must be seen to generate a significant return. To ensure that innovation investments generate desired returns, are spent most effectively, and remain a priority in the face of austerity measures, the Government of Ontario must obtain the most rigorous and reliable estimates of the impacts of its innovation support programs.

Measuring the impacts of the Government of Ontario's investments in innovation requires four steps. First, cataloguing innovation investment programs highlights what constitutes an investment. At the program level, the Panel identified six classes of Ontario innovation support programs: direct academic support, public and not-for-profit research organizations, innovation intermediaries, direct business support, indirect business support, and public procurement.

Second, identifying program objectives delivers guidance on what impacts to expect — that is, what can and should be measured for a program. The Panel identified the likelihood of seven types of impact for each of the six classes of Ontario innovation support based on stated program objectives (see Table 1).

Third, collecting data, either from administrative records and surveys or through program design, determines the most appropriate measurement technique. The robustness and reliability of an impact measurement depend on the type and quality of data collected. The ability to use sophisticated best practice econometric approaches to program evaluation is sometimes limited by a lack of data.

Fourth, using leading-edge econometric approaches to program evaluation (random field experiments, regression discontinuity design, matching estimation, and difference-in-difference estimation) can provide robust and reliable measurements of program impact. These approaches require skilled and experienced analysts and a significant time commitment to interpret results. The Panel identified how and when to best employ these measurement tools for Ontario's innovation support programs (see Table 2).

Program impact measurement can provide robust and reliable estimates of the returns to innovation investments. There is, however, an important and fundamental trade-off between data requirements and the timeframe in which impact measurement can be conducted and the robustness of these estimates. If the

Table 1

Likelihood of Impact of Ontario Innovation Investment Programs

Program Type / Types of Impact	Knowledge Generation	Creation of New Ventures (Entrepreneurship)	Access to Capital	Employment	GDP/ Output	Taxes	Social
	Likelihood of Impact						
Direct academic support	High	Low	n/a	Moderate	Low	Low	Moderate
Public and not-for-profit research organizations	High	Low	n/a	Moderate	Low	Low	Moderate
Innovation intermediaries	Low	Moderate	Moderate	Moderate	Low	Low	Low
Direct business support	Moderate	High	High	High	Moderate	Moderate	Moderate
Indirect business support	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate
Public procurement	Low	Low	n/a	High	High	High	High

Table 2

Suggested Measurement Methodologies by Innovation Program Type

Program Type	Suggested Measurement Methodology
Direct academic support	Regression discontinuity design Indicator-based frameworks Case studies
Public and not-for-profit research organizations	Indicator-based frameworks Case studies
Innovation intermediaries	Random field experiments Matching estimation Client-based surveys
Direct business support	Random field experiments Matching estimation Client-based surveys
Indirect business support	Regression discontinuity design Difference-in-difference estimation
Public procurement	Difference-in-difference estimation Matching estimation

goal of measurement is to produce estimates of *short-term* impact, the best source of data is a properly designed client-based survey that minimizes the subjectivity of responses. If the goal of measurement is to firmly establish rigorous, reliable, and *long-term* causal estimates of program impact, state-of-the-art approaches, like random field experiments and regression discontinuity design, require a specific program design, a substantial quantity of data, and a significant amount of time. Ultimately, the feasibility of a measurement methodology depends not only on the goals of measurement, but also on the objectives and structure of an innovation program, which determine the expected socio-economic impacts.

INNOVATION ECOSYSTEM ASSESSMENT

Program impact measurements alone cannot capture the nature of innovation. Innovation is not a process isolated at the program level, with a linear relationship from investment to impact. Assessing the full impact of innovation investments requires capturing their contributions to the functioning of the entire innovation system. The Panel developed its firm-centric innovation ecosystem framework that conceptualizes innovation as the result of an intricate set of activities and linkages between innovation actors. The sheer volume of interactions and complicated feedback loops makes it difficult to understand the workings of an innovation ecosystem at the micro level. Instead, the crucial components for analysis are the key aggregate behaviours that emerge from this network of micro-interactions (as illustrated in Figure 1):

- *Knowledge generation* – Created in universities, colleges, public research organizations, governments, and firms, and codified in the forms of publications/patents/products or embodied in human capital, knowledge represents the ideas from which novel products and processes emerge.
- *Innovation facilitation* – The enabling of innovation is often performed by innovation intermediaries, through financial support, networking capabilities, and mentoring/advice.
- *Policy-making* – Six types of government policies and regulation can influence the health of an innovation ecosystem: competition policy; trade policy; intellectual property; sector-specific regulations; good governance, transparency, and corruption; and public innovation platforms.
- *Demand* – This behaviour is a reflection of the needs and preferences of market customers, other end users, and governments.
- *Firm innovation* – This is the central behaviour of the innovation ecosystem with firms playing the principal role in translating ideas into innovation by using the resources of the ecosystem.

The state of the five aggregate behaviours governs the effectiveness of the innovation ecosystem in fostering and sustaining firm innovation, and ultimately generating impact. It follows that the state of the entire ecosystem, or regional and sectoral ecosystems, can be assessed by examining indicators of the five aggregate behaviours of the firm-centric innovation ecosystem. The firm-centric innovation ecosystem is an approach to assessment, rather than to measurement.

EVALUATING THE ONTARIO INNOVATION ECOSYSTEM

Program impact measurements and indicators of aggregate behaviours can be combined to quantitatively evaluate the state of the innovation ecosystem. This involves developing a scorecard that organizes rigorous estimates of the returns to innovation investments at the program level by the ecosystem behaviour the program supports. Measurements and indicators can be compared over time or across jurisdictions. Developing an Ontario scorecard that fully reflects the Panel's firm-centric innovation ecosystem framework is currently not feasible because of insufficient data. Rigorous estimates of the impact of the suite of innovation support programs (six classes) have not been obtained according to the measurement approaches identified by the Panel. With the exception of knowledge generation,

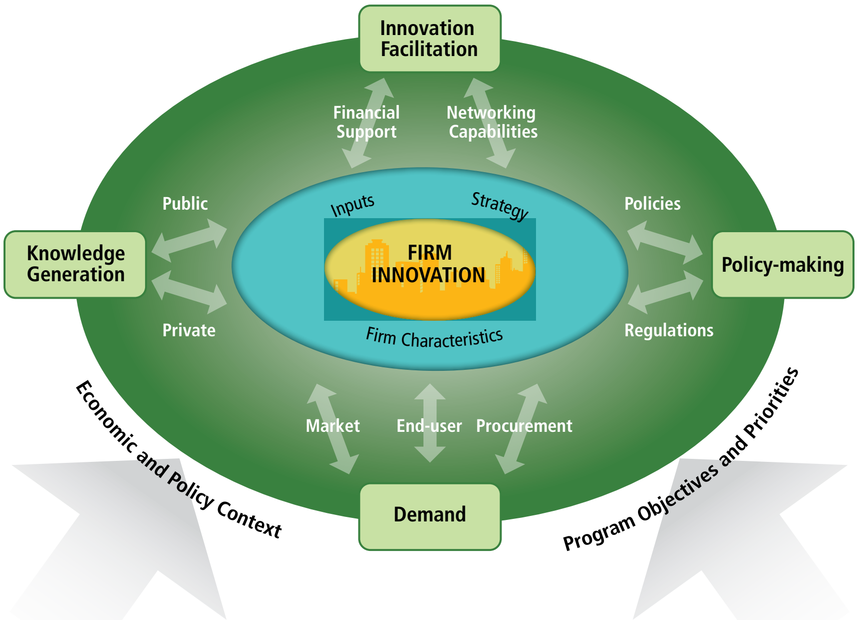

Figure 1
The Firm-centric Innovation Ecosystem

much of the data for indicators of the aggregate behaviours of the innovation ecosystem have not yet been collected. In fact, viable and agreed-upon indicators for policy-making and demand have not even been developed. Existing data only allow for the development of an incomplete scorecard; however, areas of Ontario strength in innovation and innovation support can be partially assessed by examining previously developed scorecards from other sources. In this sense, scorecards reside on a continuum, with the Panel's firm-centric innovation ecosystem approach as the best practice and previous scorecards as the best accomplished to date.

This largely quantitative approach may overlook contextual features of an innovation ecosystem and hide details of the interactions and feedbacks at the micro level. Quantitative analysis alone does not capture shifts in the mix, or expansions in the scope, of innovation investments and innovation policy. As such, more qualitative methods should complement quantitative approaches to innovation ecosystem assessment. Innovation case studies and surveys can be conducted of specific innovation actors (e.g., innovation intermediaries), economic sectors, or entire ecosystems. Governments can use independent innovation investment and ecosystem evaluations to increase the effectiveness of the ecosystem by pinpointing bottlenecks and leverage points for innovation investments and policy to exploit. These evaluations, often conducted by blue ribbon panels of foreign experts, enable governments to monitor the state of the innovation ecosystem. Continually commissioning and updating evaluations of the impact of innovation investments and the state of the innovation ecosystem are standard practice in many leading innovation countries.

Applying the Panel's overall approach requires several commitments. First, to rigorously and reliably estimate program impact, according to the methodologies identified by the Panel, program evaluation would ideally be built directly into the design and delivery of innovation programs themselves. Second, more indicators of the five aggregate behaviours require collection, based on data from repeated cross-sectional observations and longitudinal data. This includes conducting benchmarking exercises of policy-making and demand. Third, the state of the Ontario innovation ecosystem could be constantly monitored by updating program impact measurements and commissioning independent innovation investment and ecosystem evaluations.

FINAL REFLECTIONS

Although a formidable undertaking requiring significant resources, measuring the impact of innovation investments ensures that the most effective innovation programs are supported with secure, stable, and sufficient funding in the face of competing demands and austerity measures. Similarly, while assessing the state of the innovation ecosystem requires significant commitment, it is critical for pinpointing bottlenecks in the ecosystem that hinder innovation, and identifying leverage points to drive innovation. In general, innovation investment and policy are likely to be most effective as a long-term strategy if based on the most robust estimates of program impact and the most up-to-date and comprehensive picture of the entire ecosystem. With shifting economic and social circumstances, it is unlikely that governments can continue doing what they always have done in innovation investment and policy. Measurement and assessment enable the most effective innovation investments and efficient innovation policies. These investments and policies are, and will continue to be, critical for Ontario’s economic and social progress.

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1

Introduction

- Why Measure the Impacts of Innovation Investment?
- The Charge to the Panel
- The Panel's Approach
- Organization of the Report

1 Introduction

> "A man was examining the construction of a cathedral. He asked a stone mason what he was doing chipping the stones, and the mason replied, 'I am making stones.' He asked a stone carver what he was doing, 'I am carving a gargoyle.' And so it went, each person said in detail what they were doing. Finally he came to an old woman who was sweeping the ground. She said, 'I am helping build a cathedral.'"
>
> Richard Hamming, *The Art of Doing Science and Engineering* (Hamming, 1997)

The sustained and rapid economic growth that began in Western countries in the mid-19th century and is experienced by many emerging economies today is due, in large part, to the systematic creation and exploitation of innovation (Jones & Romer, 2010). Innovation is the predominant source of the new or improved products, processes, and methods of marketing and organization that drive the competitiveness of our business sector; generate the income that sustains our standard of living; alter the way we interact with each other and the natural world; and solve (and sometimes create) the technical and social problems we face. By corollary, it is also well established that when innovation is non-existent (Caselli, 2005) or lagging (CCA, 2009), industries and jurisdictions stagnate or fall behind in economic progress and prosperity (Moretti, 2012).

Innovations do not miraculously appear like manna suddenly and unexpectedly. Rather, more like a cathedral, an innovation emerges from the activities of a wide variety of individual actors linked together in a complex system of interaction. As the parable offered by prominent mathematician Richard Hamming (1997) illustrates, it is often characteristic of actors in any system — be it building cathedrals or creating innovations — to maintain a relatively myopic view of their relationship to the system, and of the nature of the system itself. Just as the stone mason and the stone carver considered the product of their craft in isolation from the construction of the cathedral, actors in innovation systems are often only aware of their individual outputs — from publications to patents to products — rather than how they contribute to the functioning of the entire system.

The notion that innovation is not an isolated process naturally leads to consideration of the simultaneous activities and linkages (interactions) between actors in an innovation system. Much as the grandeur of a cathedral depends on the designs of architects, the masonry and glasswork of craftspersons, and even the sweeping of labourers, the vitality of innovation depends on the aggregate level behaviours that emerge from a network of micro-interactions.

1.1 WHY MEASURE THE IMPACTS OF INNOVATION INVESTMENT?

It is widely accepted and understood that innovation is critical to economic competitiveness and social progress. To this end, the Ontario Ministry of Research and Innovation launched the Ontario Innovation Agenda in 2008, with the explicit aim of strengthening Ontario as a leading, innovation-based economy (Government of Ontario, 2008). It is, however, certainly valid to wonder why it is necessary to measure the *impacts* of innovation investments. For example, investments that are straightforward to measure, such as spending on R&D, machinery and equipment, information and communication technologies, and highly qualified personnel, have been repeatedly shown to lead to innovation (CCA, 2009; OECD, 2012; Miller & Côté, 2012; Hawkins, 2012). Why not just measure these *inputs*? Or why not simply take stock of *outputs*, like publications, patents, products, or new firms, which, through relatively well-understood economic and technological mechanisms, lead to innovation? Furthermore, since growth accounting (CCA, 2009) and econometric techniques (Hall *et al.*, 2010) allow measurement of innovation in the form of multifactor productivity, why not just stop there and acknowledge the chain of causal command from innovation to economic growth to social impact? Presumably, significant resources and a lot of head scratching could be saved if any one of these approaches were to be followed. Why then are policy-makers concerned with measuring impacts?

First, in the post-downturn era of spending austerity, governments are not only faced with competing demands for public funds, but also with increased pressure to demonstrate value-for-money. With a surfeit of public spending priorities, some of which, like health and education, lead to quickly visible and politically advantageous support, public investments of any kind must be seen to generate a significant return. In this sense, despite the well-accepted link between innovation investment and growth, the positive impact of these investments, much like Voltaire's God, must exist to justify this use of public funds. Even when the goal of public spending is to enhance economic competitiveness and create jobs, short-term elixirs, like industry subsidies and infrastructure projects, may generate more immediately noticeable impacts and create more political capital.

Second, setting aside political spending prioritization, accepting the link between innovation investment and economic growth does not necessarily shine light on which investments are most effective in generating innovation (and through what channels this may occur), and the social impacts that do not automatically flow from economic growth itself. Given that a host of challenges make the task of measuring the impacts of innovation investments conceptually daunting, only by carefully tracing the flow of investments through an innovation ecosystem can one arrive at an understanding of the relationship with impact. As the well-known motto of Nobel laureate Heike Kamerlingh Onnes suggests: “Door Meten tot Weten" (knowledge through measurement).

1.2 THE CHARGE TO THE PANEL

In July 2011, the Ontario Ministry of Research and Development asked the Council of Canadian Academies (the Council) to appoint an expert panel to answer the question:

> *How can the actual and potential outcomes and impacts of Ontario government spending on innovation and scientific activities be measured, including but not limited to the effects on GDP in Ontario, generation and transfer of knowledge; creation of new ventures; and access to seed, development and growth capital?*

The charge was further specified in three sub-questions:

1. *Based on the rigorous review of current studies and the identification of the most appropriate evaluation methods, is it feasible to build a model to quantify the returns on innovation investment of the government of Ontario in terms of socio-economic effects such as output, employment, tax, creation of new ventures, development of entrepreneurship and social impacts?*

2. *How can the returns (socio-economic impacts) on innovation investments by the government of Ontario be defined and evaluated?*
   2.1 *What methods for assessing and quantifying the actual and potential returns on innovation investments are used by other jurisdictions?*
   2.2 *How can these methods be applied to Ontario?*

3. *Identify Ontario’s areas of strength in innovation and innovation support.*

1.3 THE PANEL'S APPROACH

The Council appointed a panel of Canadian and international[1] experts (The Expert Panel on the Socio-economic Impacts of Innovation Investments) from the academic, business, and public sectors. Panel members drew on their own extensive practical experience in impact assessment, as studied in various jurisdictions around the world, and as witnessed in the private sector with perspectives on outcomes from small, medium, and large corporations.[2] The Panel also benefitted from expert witness presentations.

In response to the charge, the Panel catalogued the portfolio of Ontario's investments in innovation, conducted an extensive academic and public policy literature review of leading-edge measurement methodologies, and explored the best international practices in impact assessment. Then, drawing on its collective understanding of innovation and experience in impact measurement, the Panel developed a new conceptual framework for understanding innovation measurement and assessment.

The Panel was charged with assessing how the impacts of innovation investments can be measured, but not with actually carrying out a measurement exercise. As such, three tasks were deemed out of scope:

- evaluation of the effectiveness of innovation support programs in Ontario;
- application of the Panel's model to measure the impact of Ontario innovation investments; and
- measurement of Ontario's strengths in innovation and innovation support.

1.4 ORGANIZATION OF THE REPORT

The report is organized as follows:

- *Chapter 2* catalogues Ontario investment support programs and discusses how program objectives provide guidance on what impacts to expect. This is followed by an overview of leading-edge methodologies drawn from public policy practice and academic literature. The chapter concludes with a discussion of how and when to use these measurement tools to measure impact.
- *Chapter 3* introduces the Panel's firm-centric innovation ecosystem framework and describes how the state of the innovation ecosystem can be assessed.

1 Countries represented by international panel members include Finland, the Netherlands, and the United Kingdom.

2 The Evidence Network (TEN) provides impact assessment services to innovation intermediaries and their government funders. Because a Panel member is a principal of the company, this report excludes TEN's impact assessment methodology in the interests of objectivity.

DEFINITIONS OF KEY TERMS

Innovation

"An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations … A common feature of an innovation is that it must have been implemented. A new or improved product is implemented when it is introduced on the market. New processes, marketing methods or organizational methods are implemented when they are brought into actual use in the firm's operations" (OECD/Eurostat, 2005).

Input

"Inputs include the labor (the range of skills, expertise and knowledge of employees), capital assets (including land and buildings, motor vehicles and computer networks), financial assets, and intangible assets (such as intellectual property) which are used in delivering outputs." (OECD, 2009).

Output

"The concept of outputs is not confined to tangible goods and social services delivered directly to citizens. The concept also includes more intangible flows of influences on the surroundings from agencies, institutions and other entities delivering on public policies. Outputs are . . . measurable either quantitatively or qualitatively. Thus outputs can be used for performance management more easily than outcomes." (OECD, 2009)

Impact

"Impacts were defined as the overall results of research on society and may include additional contributions . . . to society. These include outputs and outcomes — two distinct concepts that are often confused. 'Outputs' represent the tangible findings of research … 'Outcomes' are the effect that these outputs have on different stakeholders, either desired or unexpected" (CAHS, 2009).

- *Chapter 4* suggests how program impact measurement and innovation ecosystem assessment can be combined and applied to the Ontario context. The chapter concludes with an overview of the commitments necessary to apply these findings.
- *Chapter 5* provides answers to the main question and sub-questions that comprise the charge, and offers some final reflections.
- *Appendix A* offers an overview of Ontario innovation support programs to provide a more comprehensive picture of the funding landscape and *Appendix B* calculates program expenditures over the 2006/2007–2011/2012 period.

2

Program Impact Measurement

- Economic and Policy Context of Innovation Investment in Ontario
- Innovation Investments in Ontario
- Measurement Challenges and Criteria
- Data Collection
- Measurement Methodologies
- Implications for Measuring the Impact of Ontario Innovation Programs
- Conclusion

2 Program Impact Measurement

Key Messages

- Measuring the impact of an innovation program requires first identifying its objectives. This provides guidance on what impacts to expect and which measurement tools are most appropriate.
- In comparing measurement methodologies, an important and fundamental trade-off exists between the robustness of an impact estimate and the data requirements — the more robust the impact estimate, the greater the data collection requirements.
- The principal challenge of measuring the impact of an innovation program is to identify a good counterfactual or control group to compare with firms or individuals participating in the program. State-of-the-art approaches include random field experiments, regression discontinuity design, matching estimation, and difference-in-difference estimation.

The Government of Ontario has long recognized the importance of innovation. Since the turn of the 20th century, government support for innovation has become increasingly widespread, contributing to innovations such as insulin (1922), the electron microscope (1938), the pacemaker (1949), the computerized geographical information system (GIS) (1960), IMAX movies (1970), the BlackBerry (1999), and remote robotic surgery service (2003). The establishment of the Ontario Ministry of Research and Innovation (MRI) in 2005 and the development of the Ontario Innovation Agenda in 2008, signalled a clear commitment to innovation as a key component of economic policy. This commitment is reflected in a varied and generous set of funding programs that provide support, to greater and lesser degrees, across a gamut of innovation activities in Ontario. Summing across pre-existing and current programs, the Government of Ontario has committed more than $3.2 billion since the establishment of MRI (see Appendix B).

> "Countries and places that invest in innovation will be home to the most rewarding jobs, the strongest economies and the best quality of life. Ontarians' ability to combine creativity and innovation is helping to provide good local jobs and putting the province on the global stage."
>
> Dalton McGuinty, Former Premier of Ontario
> (Government of Ontario, 2011)

To ensure that these innovation investments are spent most effectively and remain a priority in the face of austerity measures, the Government of Ontario must obtain the most rigorous and reliable estimates of the impacts of these programs. Measuring the impact of an innovation program requires first identifying its objectives. This highlights the aspects of innovation that the program supports (i.e., generation of knowledge, access to capital, etc.); the impacts that may be expected; and the time periods in which they may occur. Identifying program objectives provides guidance on what data to collect and which measurement tools are most appropriate.

This chapter begins with a discussion of the overarching economic and policy context for innovation investment in Ontario. Next, six classes of Ontario innovation support programs are explored and their objectives highlighted. With this understanding in hand, the chapter presents measurement challenges and high-level measurement criteria that determine the choice of measurement tools. Following this is an overview of the leading-edge methodologies drawn from public policy practice and academic literature, including case studies, surveys, indicator approaches, general econometric methods, and econometric approaches to program evaluation. The chapter concludes by identifying how and when to best use these measurement tools for Ontario innovation support programs.

2.1 ECONOMIC AND POLICY CONTEXT OF INNOVATION INVESTMENT IN ONTARIO

Ontario is by far the largest economy in Canada. In 2011, Ontario's GDP was $655 billion, representing 37.1 per cent of Canada's total GDP and more than the GDP of Quebec ($346 billion) and Alberta ($295 billion) combined (Statistics Canada, 2013a). By global standards, Ontario is the 18th largest world economy (OECD, 2013). In 2011, Ontario internationally exported $155 billion, and imported $255 billion, of goods and services, leading to a trade deficit of $100 billion (Government of Ontario, 2013a).

Although nearly 6.8 million people are employed in Ontario, the unemployment rate of 7.7 per cent is high relative to other provinces — only the Atlantic provinces have higher unemployment (Statistics Canada, 2013b). While the province ranks fourth highest in GDP per capita ($46,303) and fourth lowest in poverty, the degree of income inequality is second only to British Columbia (Osberg & Sharpe, 2011). Many other indicators of individual economic and social well-being haven fallen in the past few years, coinciding with the general downturn in the Ontario economy. The Commission on the Reform of Ontario's Public Services was tasked in 2012 with developing recommendations for dealing with a large deficit of $14 billion (2.3 per cent of GDP) and growing debt, which currently stands at $214.5 billion (35 per cent of GDP). The Ontario Jobs and Prosperity Council (2012) highlighted innovation as the driving force of economic prosperity in its recent recommendations for enhancing the competitiveness of the Ontario business sector.

It is important to consider the role of Ontario in the integrated Canadian-U.S. economic system. Historical ties and proximity to the world's largest economy have created a double-edged sword for Ontario. On the one side, this stroke of geographic good fortune has provided Ontario with access to a virtually insatiable market, leading to highly profitable trade relationships (77 per cent of Ontario's trade in 2011) and strong GDP growth (Government of Ontario, 2013a). On the other side, this situation has created a so-called "low innovation equilibrium," where the innovation strategy of many firms is truncated to the bottom rungs of the value chain as commodity suppliers and low value-added producers (Nicholson, 2011). With growing challenges facing all modern economies — intensifying global competition, increasing demand for energy and other natural resources, aging populations, and the transforming of business models through information and communication technologies (ICT) — this business strategy is likely to become increasingly untenable in the coming years. Supporting the innovation ecosystem, and harnessing its innovative capacity, is therefore likely more important than ever before.

As mentioned, the Government of Ontario has focused on innovation as a key component of economic policy, especially in recent years. While the 2004 provincial budget explicitly articulated the relationship between the commercialization of research, innovation, and economic prosperity, in 2005 the government "first began to frame a coherent strategy for economic intervention around the idea of innovation … targeting human resources development for innovation … [forming] MRI and the Ontario Research and Innovation Council … [initiating] a series of targeted investment programs [and facilitating] the commercialization of basic research" (Sharaput, 2012). In general, the innovation strategy was heavily focused on the development of highly qualified personnel (HQP): ensuring a supply of innovation-generating researchers, enhancing skilled labour, and retraining other workers to facilitate the transition from a manufacturing to a knowledge-based economy (Sharaput, 2012). This approach to spur innovation-led economic progress through the generation of knowledge is reflected in the following statement from MRI's 2006 strategic plan:

> Understanding the value of all new ideas, recognizing the benefits they provide to society as a whole, and rewarding those who create knowledge and those who put it to use to achieve growth and prosperity. An innovation society has both the respect for the education and research that drive the creation of new ideas and the nimbleness to act on opportunities to achieve their full value.
>
> (Government of Ontario, 2006)

In April 2008, MRI launched its central strategic policy document — the Ontario Innovation Agenda (OIA) — to support innovation as a driving force of the Ontario economy (Government of Ontario, 2008). By investing heavily in areas where Ontario is, or will be, identified as a global leader — the bio-economy and clean technologies; advanced health technologies (oncology, regenerative medicine, and neuroscience); pharmaceutical research and manufacturing; and digital media and information and communications technologies — the OIA lays the foundation for implementing and delivering important government initiatives that support a strong, innovative economy and "good jobs for Ontario families" (Government of Ontario, 2008). As a policy framework designed to improve Ontario's productivity, competitiveness, and prosperity by strengthening the pathways that connect researchers, businesses, and global markets, the stated objectives of the OIA are to:

- "extract more value from all provincial investments in research and innovation;
- attract the best and brightest innovators and entrepreneurs from around the world and keep home grown talent here;
- invest in, generate and attract a workforce with first-rate skills in science, engineering, creative arts, business and entrepreneurship;
- stimulate increased private-sector investment in knowledge-based companies and capital that boosts productivity;
- be globally recognized as a commerce-friendly jurisdiction that supports the growth of innovative companies and activities."

(Government of Ontario, 2008)

The commitment of the Government of Ontario to innovation-driven economic policy is clear (Sharaput, 2012); however, in the context of measurement, explicit objectives and expected impacts of innovation investments are not immediately apparent at this overarching level. Without clear and explicit objectives, it is not possible to measure impact. It follows that measurement of the impact of Ontario innovation investments requires examining objectives at the program level.

The Panel identified the innovation support programs outlined in the next section by examining publically available annual reports and budgets of Government of Ontario departments.

2.2 INNOVATION INVESTMENTS IN ONTARIO

Innovation in Ontario is predominantly supported by the federal government. As such, it is difficult to separate the individual impacts of federal and provincial sources of investment, owing to complex program overlaps, linkages, partnerships, and contributions from other sources. For instance, at the federal level, there is a complex array of direct and indirect funding programs. The Tri-Agency (Natural Sciences and Engineering Research Council of Canada; the Canadian Institutes of Health Research; and the Social Sciences and Humanities Research Council of Canada) comprises a major share of basic and applied research funding. In addition, the federal government offers programs that provide direct support for business R&D (e.g., Industrial Research Assistance Program, Strategic Aerospace and Defence Initiative) and the Scientific Research and Experimental Development tax incentive program. The *Review of Federal Support for Research and Development* (Industry Canada, 2011a) provides an excellent summary of federal support programs.

At the broadest level, the most widely cited indicator of a jurisdiction's financial investment in innovation is gross domestic expenditure on research and development (GERD), which measures aggregate intramural spending from all sources, including the federal and provincial governments, higher education sector, business sector, and foreign sector. Figure 2.1 illustrates that in 2010 Ontario ranked second in Canada in GERD intensity — the ratio of total expenditure on R&D to GDP — at 2.23 per cent trailing only Quebec (2.49 per cent) (Statistics Canada, 2012). While consistent with the Organisation for Economic Co-operation and Development (OECD) average (2.32 per cent) and exceeding the Canadian average (1.85 per cent), Ontario trails world-leading jurisdictions and comparably sized countries by a significant amount: Massachusetts (6.90 per cent), California (4.60 per cent), Israel (4.40 per cent), and Finland (3.90 per cent) (OECD, 2012). While some jurisdictions explicitly, and most others implicitly, aim to increase GERD through spending and other policy initiatives (Government of Ontario, 2010a), this indicator hides important details of the source of financial support, and exactly which aspects of innovation are being targeted.

It is challenging to determine precisely the funding magnitude of Government of Ontario innovation support programs for similar reasons. The Ontario Research Fund, the main direct funding program, has invested nearly $1 billion since 2004 in basic and applied research (Government of Ontario, 2013b). Ontario's R&D tax credit program, the Ontario Innovation Tax Credit, totalled $465 million in 2010 (Government of Ontario, 2013f). Figure 2.2 provides a high-level overview of these public-funding initiatives over the 2006–2011 period by form of support: academic and public research, innovation intermediaries, and direct and indirect business support. These data show that 34 per cent of provincial spending is dedicated to academic research and public research, 11 per cent to innovation intermediaries, 12 per cent to direct business support, and 43 per cent to indirect business support (see Appendix A for a more fine-grained breakdown). Table 2.1 categorizes Ontario innovation support programs into six classes: direct academic support, public and not-for-profit research organizations, innovation intermediaries, direct business support, indirect business support, and public procurement.[3] The next six sections examine these program classes to determine their objectives and what impacts may be expected.

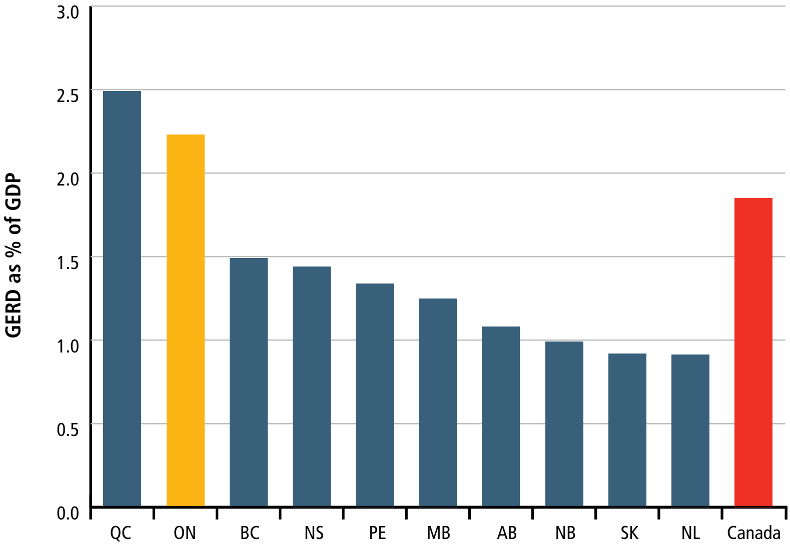
Direct Academic Support

There is strong support for higher education expenditure on R&D (HERD) in Ontario. In 2010, although fourth among Canadian provinces in HERD intensity (0.75 per cent of GDP), Ontario outstripped the OECD average of 0.55 per cent (see Figure 2.3) (Statistics Canada, 2012; OECD, 2012).[4] In total, Ontario performed 40 per cent of HERD ($4.6 billion) in Canada in 2009, with 9.7 per cent funded by the business sector ($473 million) (Statistics Canada, 2012).

The Ontario government has a suite of programs that provide direct support for academic research. The main MRI funding program is the Ontario Research Fund (ORF), created in 2004 to "support scientific excellence by supporting research that can be developed into innovative goods and services that will boost Ontario's economy" (Government of Ontario, 2013b). The ORF is divided into ORF-Research Excellence (ORF-RE), which supports the direct and indirect operational costs of research; and ORF-Research Infrastructure (ORF-RI), which covers up to 40 per cent of the capital costs of acquiring and developing research infrastructure and provides the matching funds for the Canada Foundation for Innovation. Announced program commitments for the ORF from 2004 to 2011 totalled approximately $1.1 billion (Government of Ontario, 2013b).

3 Figure 2.2 and Table 2.1 differ slightly in their presentation of programs because of data unavailability.

4 The data presented in Figure 2.3 are categorized by performer: in this case, the higher education sector. Statistics Canada also collects data by funder; however, these data are not overly useful for separating the contributions of federal and provincial contributions to HERD. While the majority of funding for HERD comes from both levels of governments, the higher education sector *itself* is still classified as the funder of its own R&D since universities have budgetary control of these public funds (Statistics Canada, Personal Communication, April 2012).



Data source: Statistics Canada, 2012.

Figure 2.1

Gross Domestic Expenditure on R&D (GERD) Intensity by Canadian Province, 2010

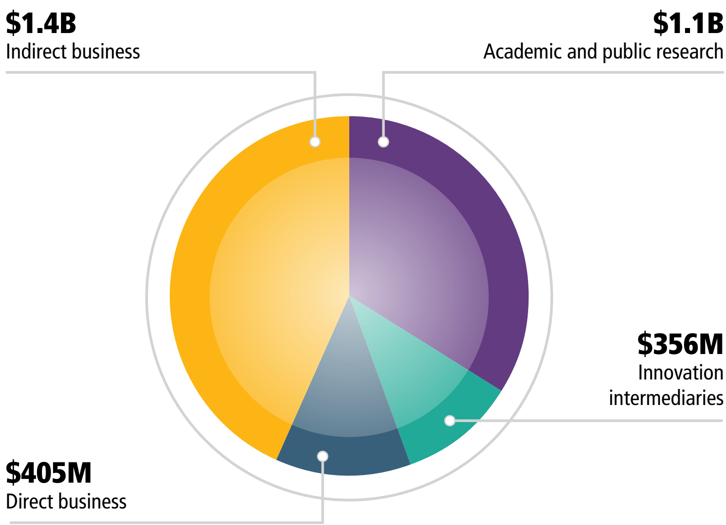


Figure 2.2

Ontario Innovation Support, 2006/2007–2011/2012

These expenditure data are gathered from the Ontario Ministry of Finance expenditure estimates from 2006/2007 to 2011/2012. Details of these calculations are provided in Appendix B.

Table 2.1

Ontario Innovation Investment Programs

Program Type	Investment Programs
Direct academic support	Ontario Research Fund (Research Excellence and Research Infrastructure) Early Researchers Award Post-doctoral Fellowship International Strategic Opportunities Program OMAFRA-University of Guelph Research Partnership
Public and not-for-profit research organizations	Ontario Institute for Cancer Research Ontario Brain Institute Perimeter Institute for Theoretical Physics Agricultural Research Institute of Ontario Ontario Forest Research Institute
Innovation intermediaries	Ontario Network of Excellence: • Ontario Centres of Excellence • MaRS • Regional Innovation Centres Business Ecosystem Support Fund Health Technology Exchange Agri-Technology Commercialization Centre Centre for Research and Innovation in the Bio-economy Water Technologies Acceleration Project
Direct business support	Ontario Venture Capital Fund Ontario Emerging Technologies Fund Innovation Demonstration Fund Market Readiness Program Investment Accelerator Fund Life Sciences Commercialization Strategy Business Mentorship and Entrepreneurship Program Biopharmaceutical Investment Program
Indirect business support	Ontario Innovation Tax Credit Ontario Business Research Institute Tax Credit Ontario Research and Development Tax Credit Ontario Interactive Digital Media Tax Credit Ontario Tax Exemption for Commercialization
Public procurement	Green Focus on Innovation and Technology Green Schools Pilot Initiative

Two additional MRI funding programs, the Early Researchers Award (ERA) and Post-doctoral Fellowship (PDF), aim to support the research efforts of junior university faculty. ERAs are awarded to researchers in the first five years of tenure track appointment to enable development of their research programs. From 2006 to 2010, $58.7 million was awarded to 419 researchers; this program is considered essential for recruiting and retaining top young academics (Government of Ontario, 2013c). PDFs are a similar funding tool intended to attract top talent to Ontario universities, with $9.8 million awarded to 196 post-doctoral fellows over the 2006–2010 period (Government of Ontario, 2013d). Appendix A provides an overview of other smaller knowledge generation funding programs administered by MRI.

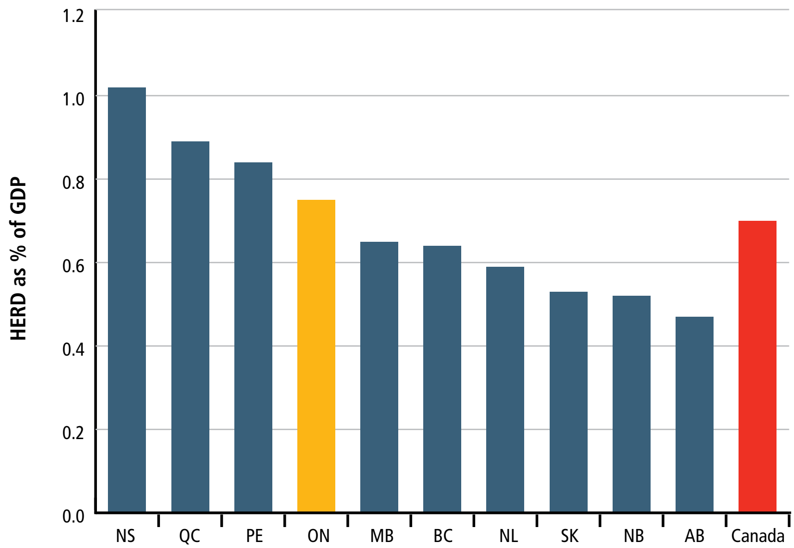
The partnership between the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the University of Guelph for the 2008–2018 period is another significant source of knowledge generation (Government of Ontario, 2013e). This partnership includes agri-food and rural research programs, laboratory services, and a veterinary clinical education program. The University of Guelph received approximately $350 million in funding in the first five years (2008–2013) (Government of Ontario, 2013e).

Public and Not-for-profit Research Organizations

From 2007 to 2011, the Ontario Institute for Cancer Research received $410 million in MRI funding, with a commitment of a further $90 million for the 2012/2013 fiscal year (OICR, 2012). In addition to conducting basic research, it is committed to commercializing its research through the Intellectual Property Development and Commercialization Fund. The Ontario Brain Institute, which supports large-scale collaborative projects involving researchers, clinicians, and industry, received $6.6 million and $7.6 million in 2011/2012 and 2012/2013, respectively (OBI, 2010).The world-leading Perimeter Institute for Theoretical Physics, has over 80 resident researchers, and has received approximately $10 million in MRI funding since its inception (Perimeter Institute, 2012). Appendix A provides an overview of public research institutes in Ontario.

Innovation Intermediaries

Innovation intermediaries are an overarching class of organizations (or groups within organizations) that endeavour to enable innovation, either directly, by supporting innovation activities of firms, or indirectly, by enhancing national, regional, or sectoral innovative capacity (Dalziel, 2010). A wide variety of organizations may be classified as innovation intermediaries: university technology transfer offices, research networks, research institutes and councils, science parks, business incubators,



Data source: Statistics Canada, 2012.

Figure 2.3
Higher Education Expenditure on R&D (HERD) Intensity by Canadian Province, 2010

industry associations, chambers of commerce, and economic development agencies. These organizations provide both direct financial support and in-kind assistance via equipment and facilities for proof-of-concept and demonstration activities.

All 22 Ontario universities have dedicated technology transfer offices (TTOs) that support commercialization of research and intellectual property in the form of contracts, licences, and spinoff companies. According to Brzustowski (2011), TTOs provide direct funding support along the path to commercial realization (from proof-of-concept) and expertise in the market potential of new ideas and patents. The Ontario Network of Excellence is an innovation network created to align all of Ontario's innovation support programs and resources. It connects all innovation intermediaries, including Ontario Centres of Excellence (OCE), MaRS, Regional Innovation Centres, and a number of sector-specific organizations. The OIA and many innovation investments are administered by OCE and MaRS.

The seven original OCEs were established in 1987 and renewed by subsequent governments. In 2004, the centres were folded into one centralized organization (the current OCE), and its mandate was changed from funding research to providing support for technology transfer and commercialization. Through a number of programs, OCE seeks to fulfil four explicit goals: transferring knowledge, educating and training young scholars, fostering and facilitating industry-academia relationships, and supporting and funding research.

MaRS has helped more than 1,300 start-up companies commercialize their ideas since 2005. It has delivered many MRI programs and provided business advisory services (advice, research, and education) to up-and-coming entrepreneurs. Its 700,000-square-foot property in downtown Toronto also provides space for researchers, entrepreneurs, and investors to interact, connect, and collaborate.

Direct Business Support

Given the critical importance of access to start-up, seed, and growth capital for innovative companies, the Ontario government initiated the Ontario Venture Capital Fund (OVCF) in 2008. OVCF is a joint initiative of the Government of Ontario (managed by the Ontario Capital Growth Corporation (OCGC)) and leading institutional investors that include TD Bank, OMERS Strategic Investments, Royal Bank of Canada, the Business Development Bank of Canada, and Manulife Financial. With an initial investment of $90 million, the fund has successfully leveraged an additional $115 million from partner institutions (OVCF, 2013). While 80 per cent of investment must be directed towards Ontario-based firms, the remaining 20 per cent may be invested in other North American venture capital funds to diversify the growth base and potentially generate more stable returns.

In 2009, the Government of Ontario established the $250 million Ontario Emerging Technologies Fund (OETF) — a funding partnership program that includes MRI (also managed by the OCGC), qualified venture capital funds, and other private investors (Government of Ontario, 2013g). OETF is a targeted program, investing directly in firms in the following focus areas of OIA: clean technologies, life sciences and advanced health technologies, and digital media and ICT. A similar program, the Innovation Demonstration Fund, administered by MRI, is designed to support green technology firms in their proof-of-concept and demonstration activities, with funding ranging from $100,000 to $4 million per project (Government of Ontario, 2013h). Since 2006, MRI has invested $73 million. Two additional major direct business support programs are the Market Readiness Program ($46 million) (Government of Ontario, 2013i) and Investment Accelerator Fund ($7 million) (MaRS, 2013), which support early commercialization activities of firms.

Indirect Business Support

The Government of Ontario also provides generous tax-based support for business R&D and innovation activities. Three major tax credits vary in their applicability by firm type and size: Ontario Innovation Tax Credit (10 per cent), Ontario Business Research Institute Tax Credit (20 per cent), and Ontario Research and Development Tax Credit (4.5 per cent). Support from these three programs and several smaller programs (e.g., Ontario Digital Interactive Media Tax Credit) totalled approximately $1.5 billion from 2006 to 2012, or 43 per cent of all funding for innovation (see Appendix B).

Public Procurement

The public procurement of products that enable the delivery of key public services can potentially create an important source of demand for innovative firms. Public health and education comprise approximately 40 per cent ($44.8 billion or 6.9 per cent of GDP) and 20 per cent ($20.4 billion or 3.5 per cent of GDP) of Ontario government expenditure, respectively (Commission on the Reform of Ontario's Public Services, 2012). Several reports have remarked on the potential for public procurement to spur innovation (Industry Canada, 2011a; Commission on the Reform of Ontario's Public Services, 2012). Two public procurement programs focus on innovation: Green Focus on Innovation and Technology and the Green Schools Pilot Initiative target Ontario firms to provide green solutions to government departments and schools, respectively. In addition, the government manages a common purpose procurement program, and directly supports market demand by offering subsidies and tax rebates for innovative energy products: solar energy systems; vehicles powered by alternative fuels; and wind, micro hydroelectric, and geothermal energy.

Summary of Ontario Innovation Programs

As mentioned at the onset of this chapter, understanding program objectives provides guidance on which impacts may be expected — that is, what can and should be measured. For instance, direct academic support programs are intended to foster high-quality academic work (knowledge generation) while direct business support is designed to provide firms with timely access to capital. Table 2.2 presents the six classes of Ontario innovation support programs according to their likelihood of producing the seven types of impact highlighted in the charge to the Panel.[5] When attempting to measure the impacts of a program, it is best to consider those impacts that a program is intended to produce as stated in its objectives.

5 The qualitative categories of high, moderate, and low are meant to highlight the general likelihood of a program generating impact based on stated program objectives.

Table 2.2

Likelihood of Impact of Ontario Innovation Investment Programs

Program Type / Types of Impact	Knowledge Generation	Creation of New Ventures (Entrepreneurship)	Access to Capital	Employment	GDP/ Output	Taxes	Social
	Likelihood of Impact						
Direct academic support	High	Low	n/a	Moderate	Low	Low	Moderate
Public and not-for-profit research organizations	High	Low	n/a	Moderate	Low	Low	Moderate
Innovation intermediaries	Low	Moderate	Moderate	Moderate	Low	Low	Low
Direct business support	Moderate	High	High	High	Moderate	Moderate	Moderate
Indirect business support	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate
Public procurement	Low	Low	n/a	High	High	High	High

2.3 MEASUREMENT CHALLENGES AND CRITERIA

The difficult, if not daunting, task of measuring the impacts of innovation investments has been on the radar of jurisdictions across the globe for several decades. This important and somewhat perplexing task faces a series of long-standing challenges that have no obvious solutions. Fundamentally, determining the impact of innovation investments requires establishing a causal relationship between a given investment and a given impact. Often this relationship is grounded in the classical linear ("science-push") model, first advanced by Vannevar Bush (1945) in *Science: The Endless Frontier*. This model posits a simple input-activity-output-impact relationship that linearly connects an innovation investment directly to an impact (e.g., research grant-research-technological development-innovation-socio-economic benefit (impact)). In principle, if this model were an accurate representation of the relationship between investments and impacts, it would be relatively straightforward to trace an impact back to the original investment. The model fails to capture a number of features of innovation that elude a simple, linear, causal story:

- *Non-linear* – The chain of causality from research to impact is neither closed nor linear. Instead, it features feedback loops that "pull" innovation and provide new inputs at various stages. Of course, not all the links of the chain need to be present, as is the case for many firms that innovate but do no R&D (OECD, 2009).
- *Dynamic* – The input-activity-output-impact relationship is not static; it is constantly evolving in the face of changing circumstances (Gault, 2010). Innovation investments generate different types of impacts over the short, medium, and long term. This time lag depends on both the nature of the innovation investment and the measure of impact employed. In fact, much innovation is "low-amplitude" and takes place over a long period, in some cases 20 years (Buxton, 2008).
- *Scope* – There is no straightforward way to define impact types (economic, social, or environmental), or to assess their distributional consequences. This is a significant issue when comparing innovation performance across jurisdictions.
- *Aggregate* – Impacts at the micro level are not easily summed to impact at the macro (aggregate) level (Buxton & Hanney, 1996).
- *Global* – In the global economy and scientific research community, the chain links are not always bounded by geography. Knowledge generated abroad affects the innovative behaviour of domestic firms (and vice versa) (Gault, 2010).

- *Attribution* – For a given impact, it is difficult to determine the exact contribution of a given innovation investment since the effect of other investments in the ecosystem, spillovers, and other exogenous factors cannot be parsed out. This is often referred to as the "attribution problem" (CAHS, 2009).
- *Causality* – An additional complication arises when assigning and establishing causality. It is not possible to observe an impact in the absence of an investment that was actually made. This is called the "counterfactual problem" since there is no experimental control for "zero investment," as it were, and no true baseline from which to measure the impact. Consider a hypothetical business support program. A firm that receives support from this program also uses an array of other resources, likely including support from other programs. If this firm generates revenue and contributes to GDP (impact), it is not possible to observe this impact in the absence of the program support.[6] As such, a business program may have positive, zero, or negative effects on firm revenue and GDP.

Taken together, these features of innovation render measuring the impacts of innovation investments — at the regional, provincial, or national level — a formidable undertaking. A wide variety of measurement tools, however, have been developed to deal with some of these challenges. The remainder of this chapter provides an overview of data collection approaches, and then presents four methodological approaches to measuring impact: case studies, indicator approaches, general econometric methods, and econometric approaches to program evaluation.

In determining the best approach, it is important to note the primary trade-off between the methodologies — the more robust the estimate of impact, the greater the data collection requirements (see Figure 2.4). Obtaining a robust and reliable estimate of impact requires collecting enough data over suitably long periods of time to use methods capable of establishing causality. Without such data, or over shorter time periods, the robustness and reliability of impact estimates are lessened. In general, after considering the measurement challenges, the Panel developed five criteria by which measurement methodologies may be judged:

- robustness of estimation (i.e., ability to establish causality);
- data requirements;
- time period;
- ability to explore a plurality of impacts, both economic and social; and
- ability to capture the nature of innovation (non-linear and dynamic).

6 The likelihood that an impact occurs in the absence of a program is sometimes referred to as incrementality.

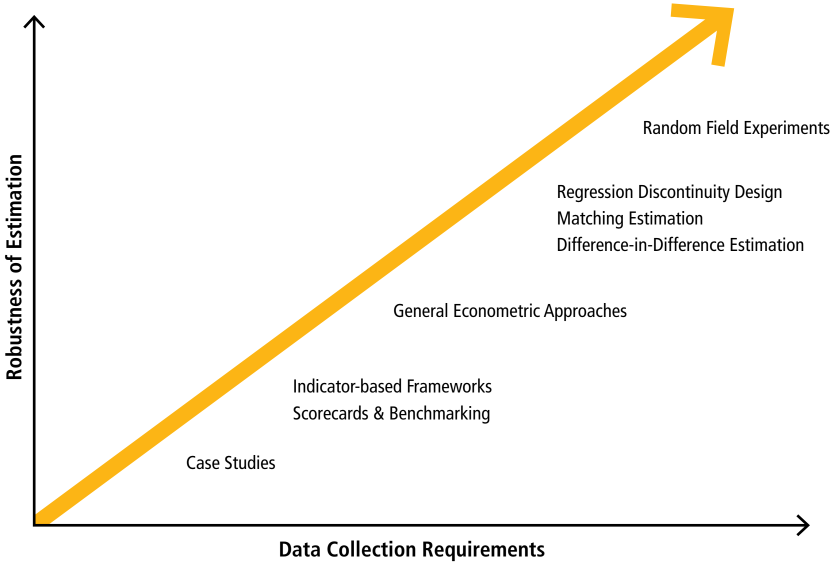


Figure 2.4
The Measurement Methodology Trade-Off

2.4 DATA COLLECTION

As mentioned, the robustness and reliability of an impact measurement depend on the type and quality of data collected. In fact, the usefulness of the sophisticated best practice econometric approaches to program evaluation is sometimes limited by lack of data. This is discussed in more detail below. The area of impact measurement uses two primary data sources: administrative data and surveys.

2.4.1 Administrative Data

Statistics Canada and most other national statistical agencies collect a host of statistics that measure scientific and innovation activities (e.g., expenditure on R&D, innovation personnel, intellectual property, etc.); firm performance (e.g., production, capital investment, corporate profits, etc.); and economic outcomes (e.g., GDP, consumption, poverty, etc.). For the purposes of examining the role of innovation in economic growth, Statistics Canada also collects data on labour, capital, and multifactor productivity for Canadian provinces classified according to the two-digit and three-digit North American Industry Classification System industrial aggregations (Baldwin *et al.*, 2007). Although provincial statistical agencies collect similar data, there are sometimes concerns about comparisons across these data sets.

2.4.2 Surveys

While the OECD has collected data on R&D since the early 1960s, the shift towards innovation as the locus of measurement is a recent phenomenon. Ground-breaking work on R&D measurement culminated in the first edition of the *Frascati Manual* (OECD, 1962), subsequent revisions, and the addition of the complementary *Oslo Manual* developed initially by the OECD and later in collaboration with Eurostat (used for the first wave of European Community Innovation Surveys, 1990-1992) (OECD/Eurostat, 2005). The *Frascati Manual* provides guidelines for collection and use of R&D data (OECD, 2002a). The first edition focused on R&D measurement in the manufacturing sector, and subsequent editions have broadened the fields of scope and improved methodology. The most recent (sixth) edition was published in 2002, and a seventh edition is forthcoming.

The *Oslo Manual*, a companion document to the *Frascati Manual*, is intended to facilitate uniform innovation data collection across countries. The standard definition of "innovation," as suggested in the *Oslo Manual*, clearly highlights its market dimension: "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD/Eurostat, 2005). The increasingly rapid pace of innovation practice, and the growing desire of governments to collect current and internationally comparable data, presents a continual challenge to keep measurement tools at the leading edge.

Following these OECD protocols, an innovation survey is designed to obtain more detailed information and data on the activities and performance of innovation actors. The most common innovation survey type examines the factors that influence firm innovation. Surveys are a valuable tool, providing policy-makers with elusive, untapped information about the conditions and activities that are conducive to innovation. The data collected are often used as the raw statistical materials for the measurement methodologies discussed in the next sections. Since the early 1990s, member countries of the European Union (EU) have conducted Community Innovation Surveys (CIS) every four years (a shorter digest survey is conducted between the four-year intervals). The survey is based on the *Oslo Manual*, with the results presented in the European Innovation Scoreboard publication series (PRO INNO Europe, 2012a). These data have been essential in documenting the state of innovation in Europe over the past two decades.

While Canada does not undertake innovation surveys with the same frequency as its European counterparts, Statistics Canada has conducted three innovation surveys (1999, 2003, and 2005); and, recently the more comprehensive Survey of Innovation and Business Strategy (SIBS) with Industry Canada and Foreign Affairs and International Trade Canada (Industry Canada, 2011b).[7] This survey covers the factors that influence *all* business strategies — innovation related and non-innovation related — to better understand the market and policy factors that influence the adoption of growth- and innovation-oriented business practices (Industry Canada, 2011b). The detailed information on business innovation strategies includes strategic and global orientation, management practices, use of advanced technology, and marketplace and competitive environments. The survey also tracks the four types of firm innovation identified in the *Oslo Manual* — product, process, and marketing and organizational — and highlights their complementarities. Key findings include the following:

- Sixty-seven per cent of Canadian firms (and 80 per cent of manufacturing firms) report having innovated during the 2007–2009 period.
- Most manufacturing firms in Canada adopt advanced technologies by purchasing them "off-the-shelf."
- Co-innovation, the introduction of an innovation that also requires the introduction of another type of innovation (e.g., a product innovation that requires a simultaneous process innovation), is common in Canada.
- While the majority of Canadian firms report that their principal market is local, there are significant differences across industries: 70 per cent of non-manufacturing firms report their principal market as local compared with 33 per cent of manufacturing firms.

As will be discussed in Sections 2.5.3 and 2.5.4, innovation surveys provide the data needed to employ some sophisticated econometric models that are capable of establishing causality from innovation investments to aggregate economic impacts (Hall *et al.*, 2010). Innovation surveys, however, unless carefully designed, are subject to response subjectivity and selection bias (Cohen, 2010). These surveys typically do not require non-innovating firms to complete the entire survey — this limits the opportunity to compare innovating and non-innovating firms (Industry Canada, 2011b; PRO INNO Europe, 2012a).

While innovation surveys collect data across a large random sample of firms, client-based surveys collect data on the participants in a given program. Typically, these surveys collect data on the activities, outputs, and customer satisfaction of

7 The SIBS sample consists of 6,233 Canada firms (across 67 industries) with more than 20 employees and revenues of at least $250,000.

recipient firms, including quantitative data on the magnitude of the support and its impact on firms (e.g., revenues, employment, publications, etc.), and qualitative data on their impressions of a funding program (i.e., what works and what does not work). In some cases, client-based surveys have been designed specifically to measure the impact of innovation — and attempt to address the attribution problem — by relying on the judgment of firms asked to assess the nature and degree of the impact of an innovation investment.

The data collected from these surveys can be quite detailed, providing timely information on how well a program has functioned and its short-term impacts. As such, client-based surveys are best used to evaluate and review ongoing programs to determine how program implementation can be improved. If the goal of measurement is to produce estimates of short-term impacts, the best source of data is a properly designed client-based survey that minimizes the subjectivity of responses.

2.5 MEASUREMENT METHODOLOGIES

2.5.1 Case Studies

As highlighted above, understanding the nature of innovation, and the relationship between investments and impact, requires familiarity with the context in which innovation takes place (Yin, 2009). In this sense, the devil is in the details. Case studies aid in understanding the nature of innovation and the impact of particular aspects on the innovation environment by offering an in-depth picture of the conditions and factors that influence innovative activities, and providing insight into the rationale behind the decisions made by innovation actors (Yin, 2009). Most importantly for impact measurement, the detail of case studies provides a window on what aspects of innovation a program supported (or failed to support) and the impacts that were achieved.

Case studies can be undertaken at a variety of levels of detail and with varying time perspectives. They can use a variety of sources, including published accounts of what has happened, documentary analysis, key informant interviews, routine data, and specific questionnaires. The generalizability of case studies is often limited because the nature of innovation, and the relationships between investments and impacts, is unlikely to be the same across all cases; however, this problem can be minimized by appropriate random or purposeful selection criteria. Case studies cannot provide a robust quantitative estimate of impact. They are best employed to complement or supplement more quantitative approaches by providing rich contextual details, illustrating the real-world complexity of interactions, and highlighting where and what types of impact to expect.

2.5.2 Indicator Approaches

Using indicators to measure the inputs, activities, outputs, and impacts of innovation is a common practice. This is not surprising since indicators[8] are widely collected, easy to interpret, clearly communicated, and readily comparable across jurisdictions (OECD, 2009). As noted, however, the task of data collection requires constant attention to the needs of policy-makers and the dynamism of innovation itself. Many jurisdictions (e.g., United States, United Kingdom, Australia, etc.) are undertaking substantial refinements of existing data, collecting new and better data, and enhancing linkages between data sets. A U.S. National Academies expert panel is currently conducting an assessment of the indicators used by the National Science Foundation to measure science, technology, and innovation; an interim report has recently been released (NRC, 2012). Likewise, the Council of Canadian Academies recently completed an assessment of the complementary roles that indicators and expert judgment should play in the evaluation of discovery science (CCA, 2012a).

Indicators, if used judiciously, can provide an excellent snapshot of the state of innovation in a jurisdiction and, if collected over a satisfactorily long period, an impression of the evolution of innovation. No single indicator, however, can adequately offer a complete picture of innovation. Each indicator has its own strengths and limitations, with some indicators more suitable for certain industries and others more suitable for certain levels of analysis. As Gault (2010) cautions, care must be taken in using indicators since a single indicator "does not tell the full story," "may need another indicator to give it meaning," "may have to be combined with another indicator," and "may give different results if it comes from a cross-sectional or panel survey."

Hundreds of indicators have been developed to measure innovation (OECD, 2012; National Science Board, 2012; CAHS, 2009), yet there is no general consensus on which indicators convey the most information about innovation. Effective use of indicators requires nesting them in a conceptual framework to measure the inputs, activities, outputs, and impacts that are theoretically, experientially, or policy relevant. Examining indicators in silos — science and technology (S&T) indicators, R&D indicators, firm profitability indicators, and the like — without a conceptual framework, eschews the non-linear and dynamic nature of innovation.

8 The National Science Board (2012) defines indicators as "quantitative representations that might reasonably be thought to provide summary information bearing on the scope, quality, and vitality of the science, engineering [and innovation] enterprises."

Without more sophisticated measurement approaches, indicators alone cannot establish causality since they do not confront the attribution and counterfactual problems discussed in Section 2.3.

Scorecards and Benchmarking

The balanced scorecard approach categorizes the inputs, outputs, and impacts of innovation according to the most important strategic directions of an organization, institution, or government. In the practice of innovation measurement, this widely used model classifies performance indicators by innovation activities, which link to wider government priorities and objectives, and compares these indicators with those of comparable, relevant jurisdictions.

Since 1999, the OECD has developed a list of S&T indicators, which it publishes every two years as the OECD STI Scoreboard. The 10th edition of this list has over 180 indicators that "present a policy-oriented review of science, technology, innovation, and industrial performance in OECD and major non-OECD countries" (OECD, 2011). *Innovation in Firms: A Microeconomic Perspective* used 20 innovation indicators to explore and compare innovation performance in firms across more than 20 OECD and non-OECD countries, including Canada (OECD, 2009). The European Commission's Global Innovation Scoreboard (GIS) seeks to compare innovation performance of the 27 EU member states to that of the major R&D spenders in the world (PRO INNO Europe, 2008).

In Canada, the federal and provincial governments have performed benchmarking exercises for the past decade, using more than 160 indicators. At the federal level, Industry Canada's Science, Technology and Innovation Council (STIC) published two State of the Nation reports in 2009 and 2011 (STIC, 2009, 2011). The Council of Canadian Academies produced a comprehensive report on the state of science and technology in Canada in 2006 (CCA, 2006), and recently released a follow-up report (CCA, 2012b). At the provincial level, the Centre for Innovation Studies (THECIS) released an innovation scorecard for Alberta in 2005 (THECIS, 2005), and Quebec produced annual S&T reports until the closure of its S&T Council in 2011. As will be discussed in Chapter 4, Ontario has developed two innovation scorecards (Government of Ontario, 2002, 2010). These sub-national benchmarking exercises are considerably more challenging, owing to both data availability and comparability across jurisdictions.

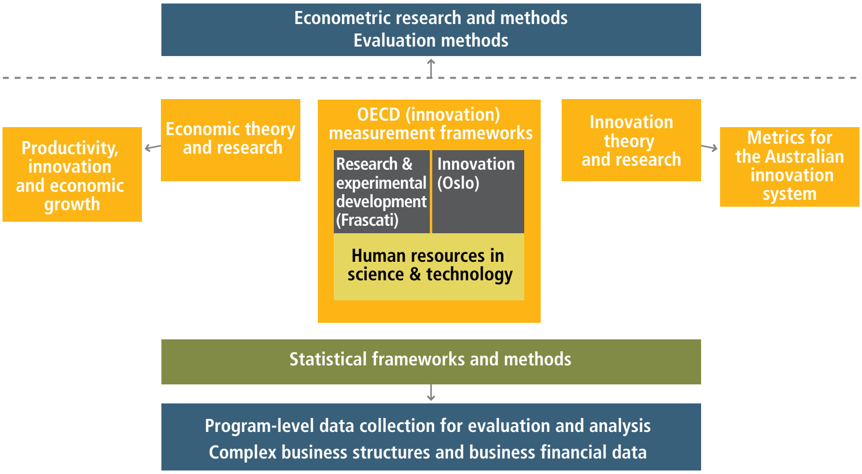
In the United States, STAR METRICS is an ongoing federally coordinated project of innovation indicator development (STAR METRICS, 2013). Championed by the National Institutes of Health, National Science Foundation, and the White House Office of Science and Technology Policy, this joint project seeks to consolidate indicators collected by various government statistical agencies into a comprehensive, nationwide innovation index (a set of innovation indicators). Some states have also developed innovation indexes including Massachusetts (Massachusetts Technology Collaboration, 2011), Maine (Camoin Associates, 2012), Michigan (University of Michigan-Dearborn, 2012), and Oregon (Oregon Innovation Council, 2009).

In the United Kingdom, Nesta has developed an innovation index using mainly the investment in intangible assets to measure the value of innovation. In support, Nesta has launched a broad range of related projects, building on research and practices developed by the OECD and EU, resulting in the 2009 publication of a pilot innovation index (Nesta, 2009). Interestingly, this index accounts for different innovation practices across sectors by explicitly profiling nine industries. Owing to gaps in the research and practice of measurement, two follow-up projects were conducted. *Driving Economic Growth* (Nesta, 2011a) explores indicators of intangible investment and return (e.g., R&D, collaborations, etc.); and *Measuring Wider Framework Conditions for Successful Innovation* (Nesta, 2011b) evaluates current data gaps and measurement needs.

Indicator-based Frameworks

The Government of Australia's *Innovation Metrics Framework Project* is an important step towards collecting the most pertinent innovation data, using related yet distinct measurement methodologies, and establishing relations across various levels of measurement analysis. It accomplishes the latter through the development of three sub-projects that integrate indicators at the economy level (sub-project 2), program level (sub-project 3), and company level (sub-project 4) into one logical framework (see Figure 2.5). The most recent report that applies this framework (*Innovation System Report*) presents a broad range of wide-scoping indicators, integrated across the aformentioned levels of analysis: expenditure on R&D by socio-economic objective and by sector, intangible asset investment, modes of innovation by jurisdiction, and new or improved innovation by mode and industry (Australian Government, 2010).

Tekes, Finland's main public research funding agency, has recently developed a leading-edge indicator-based framework (Tekes, 2012). While this framework adopts a straightforward input-activity-output-impact approach, it provides a judicious set of indicators that measure inputs/activities/outputs insofar as they are linked to four classes of impacts: economy and renewal, environment, well-being, and skills and culture. For example, the economy and renewal impact category matches indicators to "impact phenomena:" national prosperity (GDP/capita); overall productivity of the economy (MFP); job creation (net job increase); high



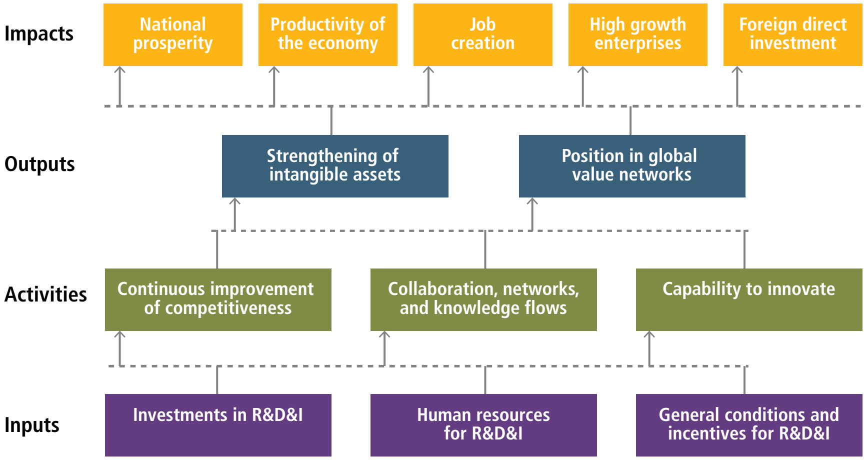
Reproduced and adapted with permission from the Department of Industry, Innovation, Science, Research and Tertiary Education of Australia (2010).

Figure 2.5
Australia: Innovation Metrics Framework

growth enterprises (share of high growth enterprises, renewal rate); and, foreign direct investments (FDI/GDP) (see Figure 2.6). This classification of indicators by impact class provides a way to qualitatively link innovation investments to impact ("hierarchy of phenomena").

Developed in 2009 to measure the impact of investments in health research, the Canadian Academy of Health Sciences (CAHS, 2009) payback model builds on the payback framework of Buxton and Hanney (1996). The Buxton and Hanney model combines an input-output-impact logic model with a balanced scorecard set of indicators, enabling tracing of investments in research through activities, outputs, and impacts; and categorizing research impact as a multidimensional phenomenon. This framework has been widely used to measure the impacts of health research in Canada (e.g., Canadian Institutes of Health Research, Alberta Innovates, and the Nova Scotia Department of Health and Wellness).

The CAHS variant of the payback framework (see Figure 2.7) adopts a logic model to categorize outputs (primary and secondary) and impacts (adoption and outcomes) into five domains, with an associated 66 indicators: advancing knowledge, capacity building, informing decision-making, economic benefits, and social benefits. As with the Tekes (2012) framework, the indicators are comprehensive,



Reproduced and adapted with permission from Tekes (2012).

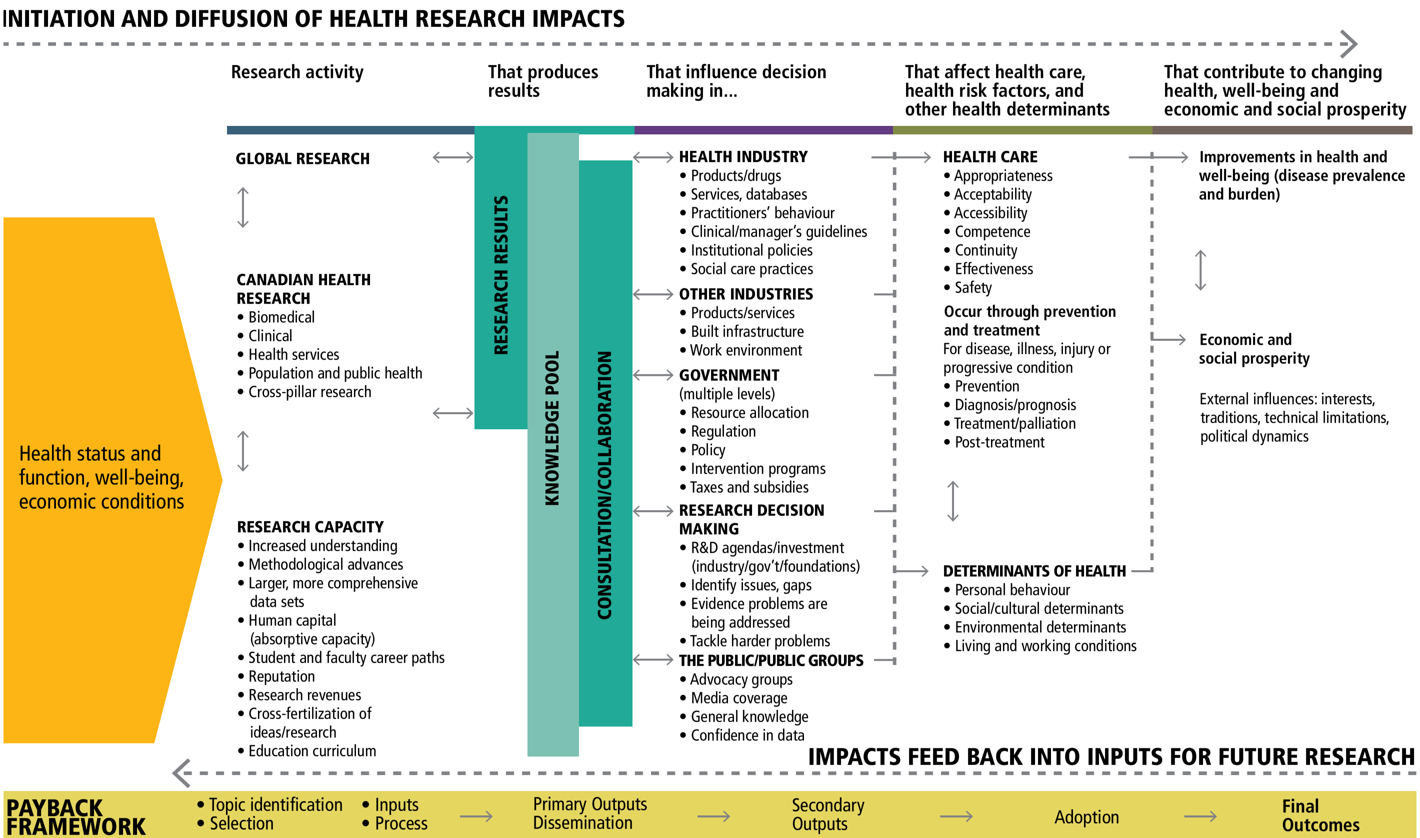
Figure 2.6
Finland's Tekes: Hierarchy of Phenomena Related to Economic Recovery and Renewal

the qualitative input-impact links are present, and the impacts are plural. However, similar to Tekes, the model does not fully capture the interactions of actors, time sensitivity of innovation investments, or behaviour in an innovation ecosystem.

These three indicator-based frameworks all provide conceptually compelling frameworks to understand the nature of innovation and the relationship between innovation investments and a plurality of impacts. Examining impacts over time or between jurisdictions, however, requires sufficiently long time series data or internationally comparable data, respectively. This is often a significant challenge. Without a counterfactual, these frameworks do not establish causality between investments and impacts.

2.5.3 General Econometric Approaches

In broad terms, to measure the impact of an innovation investment, econometric models examine the effect on firm innovation behaviour. These models start from the premise that firms aim to earn profit, using inputs (physical capital, financial capital, R&D capital, and labour) to produce products with market potential. In so doing, firms generate economic impact by developing new products, markets, and exports, and thereby contribute to GDP and tax revenue. These economic



Reproduced and adapted with permission from the Canadian Academy of Health Sciences (2009).

Figure 2.7

Canadian Academy of Health Sciences: The Payback Model

activities also contribute directly to social well-being through standard of living (GDP/capita), employment, and new health and environmental products; and indirectly through public services.

The basic version of an economic model of innovation starts with a simple mathematical representation of output as a function of inputs. This production function can be expressed as,

(1) $Y_i = F(L, K, R^I, R^E, A)$,

where Y_i denotes final output (products) of a firm i, a function of the following inputs: L is a measure of the quality of labour employed; K is the physical and financial capital utilized; R^I is a measure of the knowledge (intangible) capital internal to the firm (e.g., R&D stock, firm learning); R^E is a measure of the knowledge capital external to the firm (i.e., held by other firms in the cluster, industry, or jurisdiction); and A is a measure of the technical progress or sophistication of the firm itself (Hall *et al.*, 2010). In this simple model, innovation investments appear as inputs (resources) to firm innovation and production.

To estimate the impact of innovation investments, theoretical models such as these are used to test the effect of change in an input (from an innovation investment) on the production of output. Indicators of the inputs, activities, and outputs of firm performance serve as *independent* variables. Econometric measurement models specify a statistical relationship between a variable of interest (*dependent* variable) and a set of independent variables, which are thought to influence or determine its value. The model is estimated using various statistical techniques to determine the relative effect of each independent variable on the dependent variable. Dependent variables can be selected at the firm level or at the economic and social impact level. The academic literature on innovation impact measurement considers a wide range of dependent variables that range from inputs to impacts (reviewed in Dalziel *et al.*, 2012). By collecting data on other inputs and making some theoretically and empirically astute simplifying assumptions, econometric methodologies can be used to *isolate* the impact of an innovation investment, measure its magnitude with statistical significance, and forecast its future impact (Hall *et al.*, 2010). For instance, studies have examined the impact on firm innovation performance of research and development (Griliches, 1998); financial capital (Czarnitzki *et al.*, 2011); and intellectual property policy (Gans *et al.*, 2008).

Econometric approaches have three main drawbacks. First, to estimate impact, these models require comprehensive data on the inputs and outputs of firm innovation and production. Often, these data are available from administrative or survey sources; however, these data must cover sufficiently long time periods (longitudinal) and have wide enough coverage (repeated cross-sectional) (Hall *et al.*, 2010). Second, constructing and estimating these models is a specialized undertaking requiring familiarity with advanced statistical techniques (Greene, 2011; Davidson & MacKinnon, 2003) and a significant time commitment to interpret results. Third, these models are based on assumptions that may not always hold in practice (Hall *et al.*, 2010; CCA, 2009). These challenges, while well recognized by econometric practitioners (Kennedy, 2008), constrain the usefulness of the approaches to measuring impact. In short, econometric approaches are only as good as the data used to populate the models, and the skills of the individuals who estimate and interpret the results.

Two leading general econometric approaches to measuring the impact of innovation investments at the economy level are discussed in the next sections: the Crépon, Duguet, and Mairesse (CDM) model and growth accounting.

Crépon, Duguet, and Mairesse Model

The CDM model (Crépon *et al.*, 1998), built on a production function, focuses on the activities of innovative firms across three sub-activities of production: the decision to invest in R&D, the production of knowledge, and the production of output. The efficiency of production, and the market price received for products (outputs), determines labour productivity. An innovation investment (either public or private) has an impact on firm production and ultimately on GDP. This model has been widely used to measure the impact of innovation investment on firms, including by 18 OECD countries in the Innovation Microdata Project. For instance, Therrien and Hanel (2010) used data from the Canadian Survey of Innovation 2005 and the Annual Survey of Manufactures and Logging to examine factors that determine the innovative behaviour, performance, and impacts on 5,355 Canadian firms during the 2002–2004 period. Applying a variant of the CDM model and controlling for some statistical issues (selection bias and simultaneity), they came to the following conclusions:

- Export outside of the United States, firm size, and use of direct or indirect government support increase the probability of innovation activity.
- Exports (both to and outside of the United States), intra-firm cooperation, and concentrated sales with an important client are positively correlated with innovation expenditures per employee.
- Firms with higher innovation expenditures per employee (input) are more likely to have higher innovation sales per employee and higher labour productivity (impacts).

(Therrien & Hanel, 2010)

The CDM model is a leading econometric approach to measuring the impact of innovation investment. It is built on a theoretically sound and conceptually appealing framework. With appropriate data and under certain assumptions (Hall *et al.*, 2010), impact can be causally attributed to an innovation investment. This approach, however, is only intended, and thus restricted, to measure firm productivity and performance — that is, it is not a model of aggregate economic and social impacts. It also does not capture the full range of activities associated with innovation. In short, the CDM model is best used to measure the impact of general innovation investments on firm performance.

Growth Accounting Framework

Pioneered by Nobel Laureate Robert Solow in 1957, the growth accounting framework is built on an aggregate production (that is, for all firms in an industry, jurisdiction, or country), and provides a methodology to decompose GDP or labour productivity growth into contributions from capital deepening, labour composition, and multifactor productivity (MFP):

- *Capital deepening* is a measure of the growth of capital per hour worked. Statistics Canada estimates this by aggregating across 28 capital asset classes and applying user cost of capital weights to each class (incorporates market return, depreciation, and taxation). This measure generally includes financial capital (Levine, 2005); R&D capital (Hall *et al.*, 2010); other intangible assets (Baldwin *et al.*, 2009); and, in some cases, social capital (Durlauf & Fafchamps, 2005).
- *Labour composition* is a measure of the growth of labour quality. Statistics Canada estimates this by aggregating across 112 classes of workers (gender, seven age groups, four education levels, and two employment categories), and applying wage weights to each class.
- *MFP* is the residual difference between total production and what portion can be accounted for by capital and labour. In the short run, this may reflect a host of factors that affect production (Diewert & Yu, 2012; Gu, 2012); however, Council of Canadian Academies (2009) argues the following in reference to the Canada-U.S. productivity gap: "The estimation of differences in MFP growth rates between Canada and the United States over long periods of time, and employing substantially identical methodologies, mitigates the possible sources of error and provides a strong indicator of differences in business between the two countries."

Like the CDM model, aggregate investments in innovation are measured as capital (including intangibles) and labour inputs, which, through the aggregate innovation activities of firms, produce economic impact in the form of GDP. The growth accounting framework is sophisticated enough to deal with almost all of the statistical issues raised in Section 2.3 (e.g., attribution, non-linearity, time, etc.);

and it has a firm theoretical base. It is employed by finance departments in many jurisdictions to measure the impact of innovation on economic performance. This framework, however, does not fully capture the richness of innovation (i.e., too many variables would lead to an over-specified model and erroneous results), nor does it necessarily measure social impact.

2.5.4 Econometric Approaches to Program Evaluation

The CDM model and growth accounting approaches are intended to measure impact of general innovation investments at the economy-wide level. Other econometric approaches have been developed to measure impact of investments on firm innovation at the program level. Consider an innovation program, such as the Ontario Emerging Technologies Fund or the Ontario Innovation Tax Credit, which provides direct or indirect business support. Estimating the impact of these innovation investments (independent variable) on firm performance (dependent variable) requires comparing the performance of the participating firms (e.g., revenue, new products, employment) to the performance of the same firms if they had not participated in the program. As discussed in Section 2.3, it is not possible to simultaneously observe firms in those two states. It follows that a principal challenge of measuring the impact of innovation investments is to identify a good counterfactual or control group for the participating firms.

Comparing the performance of participating firms with the entire population of non-participating firms is generally not a valid approach since the decision to participate in a program is not random. Participating firms are likely to behave in different ways, use different resources for innovation, and have different characteristics than non-participating firms. As such, non-participating firms are generally not a valid control group. If, for instance, an innovation support program awards grants based on the quality of the grant application/proposal, firms that receive funding (participating firms), by the very nature of having a strong application, are likely to perform well even in the absence of the program. This is not to say that the program has no impact on participating firms, but rather that these firms are more likely to perform well than non-participating firms even in the absence of the grants (Jaffe, 2002). In this case, comparison of participants and non-participants would overestimate the impact of the grants on firm performance. It is thus critical to identify the non-participating firms that are comparable to participating firms among the pool of all firms (i.e., find/create a valid control group).

Several techniques have been developed to find the best control group and ultimately provide a causal estimate of impact. Four best practice econometric program evaluation techniques are presented in the next sections: difference-in-difference estimation, matching estimation, regression discontinuity design, and random field experiments. The first three techniques identify a sub-group of non-participating firms that are similar enough to the participating firms for the comparison to be valid, while the last technique introduces randomization in the assignment to the program. For all four methods, the impact of the program is the difference in average performance between the two groups. The main difference between the techniques is the way the control group is constructed.

Difference-in-difference Estimation

This estimation technique requires a change in a public policy or the introduction of a new program that affects some individuals or firms and not others (control group). In these so-called "natural experiments" the experimenter does not induce the treatment — that is, no random assignment is involved. In most cases, it consists of a public policy change that affects a sub-group of participants while the remainder of the participating group, which must be comparable, is unaffected by the change. In other words, the only difference between the two groups is the policy change. Unfortunately, it is often difficult to find a comparable sub-group of participants that remain unaffected by the policy change (i.e., federal programs). Without an adequate control group, this approach cannot establish causality.

Several recent studies have exploited a change in tax policy as a natural experiment to measure the impact of R&D tax credits (Paff, 2005, in the United States; Hægeland and Møen, 2007, in Norway). Brouillette (2011) used the introduction of a 10 per cent provincial R&D tax credit in British Columbia to estimate the incremental impacts on business R&D conducted by B.C. firms (treatment group). Alberta firms were used as the control group since they were not subject to a policy change and are likely to be similar, on average, to B.C. firms. Although the British Columbia and Alberta economies might have been affected in different ways by macro-economic factors during the period, Alberta was the best counterfactual to British Columbia for at least three reasons. First, both provinces' share of total business enterprise expenditure on R&D (BERD) in Canada was similar. Second, the economies of both provinces have relied significantly on natural resources. Third, the government of Alberta did not grant fiscal incentives to support BERD before 2009, a situation identical to the pre-reform period in British Columbia.

Matching Estimation

This estimation technique measures the impact of a program by finding, for each participating firm, a non-participating firm that is statistically similar (Todd, 2008). In other words, the method consists in finding non-participating firms so similar to the participating firms that the performance of the former would be the same as the outcome of the latter if they had not participated in the program. The assumption is that all the information available on firms (e.g., size, sector, region, etc.) is sufficient to control for the non-random decision to participate in the program. This technique can be used to evaluate almost any program (Dehejia & Sadek, 1999); however, it requires a significant amount of information on firm characteristics (Todd, 2008).

For example, a matching estimator could be used to estimate the impacts of the refundability and rate for Ontario firms participating in any of the tax credit programs (recall Table 2.1). Each firm receiving the tax credit would be matched with a non-participating firm with similar characteristics such as taxable income and capital, employment, region, and sector. Application of a matching estimator in this case would identify the impacts of both the refundability and the tax credit for participating firms.

Regression Discontinuity Design

Regression discontinuity design (RDD) requires that a program funding mechanism follow a specific design (Lee & Lemieux, 2010). In general, funding proposals or candidate firms have to be evaluated and ranked according to some pre-specified criteria. Then, only the proposals that rank above a pre-specified threshold are funded. The underlying assumption is that around the threshold, participating and non-participating firms are similar enough that it is as if they have been randomly assigned to the program. In addition to requiring a specific program design, this technique also requires a sufficiently large number of firms just below and just above the threshold (Lee & Lemieux, 2010).

This approach could be used to evaluate a program designed so that firms interested in receiving support submit a proposal, which would be ranked according to some criteria. All firms above a pre-determined threshold would then be funded while the others would not. A more inclusive variant of this project would require that all submitted proposals receive some support, but that proposals above the threshold would receive extra support. The effectiveness of the program would be assessed by comparing the outcomes of the group of firms just above the threshold with the group just below. The Panel is not aware of any studies that have used RDD to measure the impact of innovation investments.

Random Field Experiments

Random field experiments (quasi-experiments or randomized trails) introduce randomization in program assignment and are considered the gold standard of program evaluation. Much like in typical scientific experiments that create a control group as a baseline for measurement, quasi-experiments create a control group by randomly assigning a “treatment” to the “assignment pool” (those involved in the experiment) (Heckman, 2010; Greenberg & Shroder, 2004). For example, in some experiments, individuals are randomly assigned to certain programs: job training (Schochet *et al.*, 2008); housing voucher (Kling *et al.*, 2007); or fertilizer (Duflo *et al.*, 2011). Randomization ensures that receiving the treatment (participating in the program) is not correlated with any other factors. That is, it controls for the effect of other factors that may affect whatever outcome is measured (e.g., finding a job, moving to a house, or crop yield). With two groups, one receiving the treatment and one not (control group), the *only* difference between these two groups is the treatment itself. It follows that if any difference between these two groups is observed, this impact is directly attributable to the treatment. For instance, if a group of individuals who receive job training find more jobs than the control group, this impact difference is the result *only* of the program. With careful program design, it is possible to dodge the counterfactual and observe the seemingly unobservable.

This methodological approach has gained considerable popularity[9] in recent years, especially in measuring the impacts of investments in economic, health, and other social programs in developing countries (Banerjee & Duflo, 2011). Quasi-experiments have been used by some North American jurisdictions for almost 50 years, beginning with income tax and health insurance experiments conducted in the United States in the 1970s (List, 2011). They have been used more recently by the U.S. Department of Education, the Poverty Action Lab at the Massachusetts Institute of Technology, the Coalition for Evidence-Based Policy, and the Campbell Collaboration at the Norwegian Knowledge Centre for the Health Services (Mullainathan *et al.*, 2011). A quasi-experimental study of the impact of Canadian child tax credits on employment and use of social services found that one-third of the decline in social assistance (impact) is directly attributable to policy designed to integrate social assistance and tax credits (investment) (Milligan & Stabile, 2011).

Measuring the impact of an innovation program would require that program applicants (firms) be randomly assigned between participation and non-participation. Consider the impact on firm performance of an innovation program that provides financial and networking/advisory services (e.g., MaRS). In this case,

9 Despite this widespread adoption and popularity, there is, perhaps unsurprisingly, an ethical debate on the random assignment to programs, which, to some, appears unfair and even draconian (Homan, 1991; Deaton, 2010). It is probable, if not inevitable, that some individuals, firms, or other stakeholders could feel slighted by the ostensive unfairness of not being assigned random support for their activities. For many innovation investments, however, it is a question of value-for-money or the magnitude of impact. As such, an experiment could ethically allocate firms to alternate investments of equal cost, but uncertain impact. This would make all firms better off than they would have been in the absence of the experiment. With appropriate program design, ethical concerns can be overcome.

the randomization could be done after the proposals are accepted but before they are funded. The accepted proposals could be randomly divided in two groups: one that received the usual support, either technical services or subsidy, and one that received extra subsidy or services on top of the usual financial support. The former group consists of the control group while the latter is the treatment (participating) group. A comparison of the performance of both groups would correctly identify the impact of the extra program support. If desired, more treatment groups could be randomly created: for example, a group with the usual program support plus extra money only, and a group with the usual support plus extra services only. This would separate and accurately measure the impact of funding and services on firm performance. This approach is extremely flexible and likely viable — a finding confirmed by a report to Industry Canada that concluded it would be feasible to conduct such evaluations in Canada (SRDC, 2008).

As with RDD, random field experiments have not been widely used to measure the impact of innovation investments (Jaffe, 2002). The Panel is only aware of one such study in this area (Nesta, 2011c). As with other econometric approaches, analyzing experimental results requires skilled and experienced analysts. In addition, the robustness and reliability of impact measurements require a relatively large population of participating firms to support the randomization of assistance. Nonetheless, this approach, as described above, has been used to measure the impact of similarly complex programs like job training and housing vouchers. The Panel recognizes that random field experiments are a best practice approach. Their lack of wide use in the innovation space does not detract from their efficacy as a leading impact measurement approach.

2.6 IMPLICATIONS FOR MEASURING THE IMPACT OF ONTARIO INNOVATION PROGRAMS

This chapter has explored various approaches to measuring the impact of innovation investments. As illustrated in Table 2.3, these approaches vary by the degree to which they meet the measurement criteria defined in Section 2.2. In a perfect measurement world, rigorous and reliable estimates of program impact would be available in real time and easily used to best allocate funds. There is, however, an important and fundamental trade-off between the timeframe and data requirements for impact measurements and the robustness of these estimates. If the goal of measurement is to produce estimates of *short-term* impact, the best source of data is a properly designed client-based survey that minimizes the subjectivity of responses. If the goal of measurement is to firmly establish a rigorous, reliable, and *long-term* causal estimate of program impact, state-of-the-art approaches, like random field experiments and regression discontinuity design, require specific program design, a substantial quantity of data, and a significant amount of time. Ultimately, the choice of measurement methodology depends not only on the goals of measurement and feasibility, but also on the objectives and structure of an innovation program. Table 2.4 provides suggested methodologies by program type.

Table 2.3

Comparisons of Measurement Methodologies

Methodology	Causality	Data Require-ments	Time Period	Plurality of Impacts	Based on an Innovation Model
Case studies		Low	Variable	✓	
Scorecards and benchmarking		Moderate	Short term	✓	
Indicator-based frameworks		Moderate	Short term	✓	✓
General econometric approaches (CDM and growth accounting)	✓	High	Long term		✓
Difference-in-difference estimation	✓	High	Long term	✓	
Matching estimation	✓	High	Long term	✓	
Regression discontinuity design	✓	High	Long term	✓	
Random field experiments	✓	Very high	Long term	✓	

Table 2.4

Suggested Measurement Methodologies by Innovation Program Type

Program Type	Suggested Measurement Methodology
Direct academic support	Regression discontinuity design Indicator-based frameworks Case studies
Public and not-for-profit research organizations	Indicator-based frameworks Case studies
Innovation intermediaries	Random field experiment Matching estimation Client-based surveys
Direct business support	Random field experiment Matching estimation Client-based surveys
Indirect business support	Regression discontinuity design Difference-in-difference estimation
Public procurement	Difference-in-difference estimation Matching estimation

2.7 CONCLUSION

While this chapter has presented state-of-the-art measurement techniques at the program level, as highlighted in the introduction, innovation is not an isolated process, but rather the result of the simultaneous activities of, and linkages between, actors (interactions) that occur in a complex system. Although sufficient to estimate the impact of a program or investment, these measurement techniques cannot capture the nature of innovation. The next chapter turns attention to precisely this by introducing the Panel's firm-centric innovation ecosystem framework.

3

Innovation Ecosystem Assessment

- Knowledge Generation
- Innovation Facilitation
- Policy-making
- Demand
- Firm Innovation
- Public-sector and Social Innovation
- Conclusion

3 Innovation Ecosystem Assessment

Key Messages

- The innovation ecosystem captures the fundamental nature of innovation — namely, that innovation is a non-linear and dynamic process, rooted in an intricate set of activities and linkages (interactions) between actors in the system.
- The innovation ecosystem provides resources for the central agent of innovation — the firm.
- The state of the five aggregate behaviours that emerge from this network of micro-interactions — knowledge generation, innovation facilitation, policy-making, demand, and firm innovation — governs the effectiveness of the innovation ecosystem in fostering and sustaining innovation, and ultimately generating impact.
- The state of the entire ecosystem can be assessed by examining indicators of the five aggregate behaviours. The firm-centric innovation ecosystem is an approach to assessment, rather than to measurement.
- Assessing the state of the innovation ecosystem is critical for pinpointing bottlenecks that hinder innovation, and identifying leverage points to drive innovation.

"It must be remembered that there is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new system. For the initiator has the enmity of all who profit by the preservation of the old institutions and merely lukewarm defense in those who gain by the new ones."

Nicolo Machiavelli, *The Prince*

While the focus on innovation as the fundamental source of economic growth and social progress is of relatively recent origin (Solow, 1957; reviewed in Jones & Romer, 2010), the focus on innovation as arising from the complex set of interactions between actors in a system is not. In 1841, German economist Friedrich List parted ways with classical economic thinking by suggesting that the growth of a national economy depended on the linkages and flows of knowledge between economic actors (Soete *et al.*, 2010). While both classical economists and List continued to assert that the accumulation of physical capital was the source of economic growth, List suggested that the improvements in, and efficacy of, capital were the result of a system, rather than of individual innovations. Instead of championing an approach to economic policy that merely corrected market failures, in *The National System of Political Economy* List (1841) argued that (German) industry should be linked to the formal institutions of science and education through a broad range of policies designed to facilitate knowledge flows and technology applications. Reflecting the insights of List, a vast literature on innovation ecosystems has accumulated over the last 25 years. Building on the seminal work of Freeman (1987), Lundvall (1992), and Nelson (1993) on national systems of innovation, this approach to conceptualizing innovation has entered the policy lexicon of most national and sub-national governments across the globe (OECD, 1997, 1999, 2002b).

Rather than conceptualizing innovation as a linear process from investment to impact, the innovation ecosystem approach captures the fundamental nature of innovation — namely, that innovation is a non-linear and dynamic process, rooted in an intricate set of activities and linkages (interactions) between actors in the system (Gault, 2010; Soete *et al.*, 2010). The sheer volume of interactions and complicated feedback loops (Kauffman, 1995; Blume & Durlauf, 2006; Arthur, 2009) make it difficult to understand the workings of an innovation ecosystem at the micro level. Instead, the crucial components for analysis are the aggregate behaviours that emerge from this network of micro-interactions. At this level of analysis, multiple actors may engage in the same behaviour, and the same actor may engage in multiple behaviours.

Investments in these behaviours constitute a much broader class of innovation investment than is normally considered by policy-makers and others involved in innovation. For instance, it is typical, at least in the Canadian and Ontario innovation vernacular, to conflate R&D with innovation. While R&D funding and performance are critical inputs to, and activities of, innovation (Hall *et al.*, 2010), the "vast majority (over 95 per cent) of innovations involve improvements to what exists in the market or in the production process" (Miller & Côté, 2012). Certainly, in some cases, these incremental innovations are the direct result of R&D performance; however, incremental innovation can also be the result of non-R&D activities. It follows that while generous and well intentioned, direct and indirect financial support for R&D is only one type of investment contributing to the innovation process. Investments in the innovation ecosystem itself, in the aggregate behaviours (the actors and their interactions), affect its health, and ultimately the prevalence and nature of innovation. This suggests a much larger and richer set of innovation investments to be considered and potentially leveraged by policy-makers.

The state of these aggregate behaviours governs the effectiveness of the innovation ecosystem in fostering and sustaining innovation, and ultimately generating impact. By analyzing the effectiveness, state, or "health" of the innovation ecosystem, it is possible to pinpoint bottlenecks in the system — whether sectoral (Malerba, 2004), regional (Bathelt *et al.*, 2011), or national (Porter & Stern, 2001; Hidalgo & Hausmann, 2009) — that hinder innovation; and to identify leverage points to drive innovation (Metcalfe, 2005). This, however, may mean shifts in the magnitude and type of innovation investments that flow to innovation actors, resulting in potential shifts in behaviour and, as Machiavelli cautioned, resistance from those with vested interests.

How does a healthy innovation ecosystem influence the likelihood and nature of innovation? In the most general of terms, an innovation ecosystem provides resources for the central agent of innovation — the firm. Since even the most imaginative and ingenious ideas and inventions are unlikely to generate economic and social impact if they sink on their voyage to the market, firms play the principal role in translating ideas into innovation. Yet, as the innovation ecosystem approach emphasizes, firms do not operate in isolation; rather, they exploit the critical resources that flow from the interactions between ecosystem actors. Just as a biological system provides the energy, water, carbon, nitrogen, and other mineral inputs that sustain organic life, an innovation ecosystem provides the knowledge, capital (physical, financial, and social), policy and regulatory conditions, and market demand resources that sustain business innovation.

This chapter combines these two premises — aggregate behaviours as the determinants of ecosystem health and firms as the central innovation agents — to develop a framework for assessing the impact of innovation investments. The Panel's firm-centric innovation ecosystem approach encompasses the five most salient aggregate behaviours of an innovation ecosystem, as illustrated in Figure 3.1:

- Knowledge generation
- Innovation facilitation
- Policy-making
- Demand
- Firm innovation

The next sections describe each of these five aggregate behaviours along with a proposed set of indicators to measure their state. After a brief discussion of public-sector innovation, this chapter concludes with a discussion of how the firm-centric innovation ecosystem approach complements the measurement methodologies presented in Chapter 2.

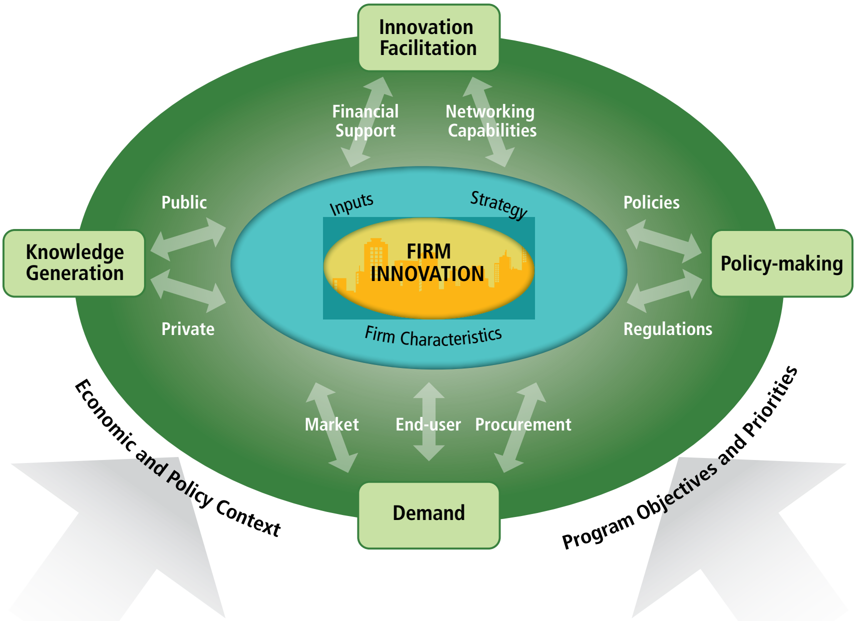


Figure 3.1
The Firm-centric Innovation Ecosystem

3.1 KNOWLEDGE GENERATION

Knowledge is the foundation of a healthy innovation ecosystem. Scientific research and education are central factors associated with long-term skills development in a nation (Jones, 2005; Romer, 1990). Knowledge and scientific research often represent the ideas from which novel products originate, the tacit comprehensions that enable incremental innovation, the insights to spot market opportunities and devise solutions to diverse problems, and the abilities to design efficient and equitable public policies. Whatever the form, from scientific publications and patents to the human capital of scientists and engineers, management and finance professionals, or other skilled workers (Lundvall, 2004; Cowan *et al.*, 2000), an innovation ecosystem is only as strong as its intellectual base. Knowledge generation is a functional activity of five actors: universities, colleges, public research organizations, governments, and firms.

The primary knowledge-generating activities of universities are the production of basic and applied research, and the training of highly qualified personnel (HQP). Excellence in research advances fundamental understanding of the science and technology that underpin innovation, and is often the source of the "big ideas" that generate revolutionary innovations. This premise was articulated by Bush (1945), further refined by Stokes (1997), and is well understood by policy-makers. Universities are also the source of highly trained individuals — scientists, engineers, business graduates, economists, lawyers, and others in the "creative class" (Florida, 2002) — who generate new ideas; improve on existing products, processes, and marketing and organizational methods; secure financing; develop business models; negotiate contracts and intellectual property agreements; and undertake other activities that are crucial to sustaining innovation and firm success (Moretti, 2012). The knowledge linkage between universities and firms that HQP represents is central to the health of an innovation ecosystem (Gault, 2010; Miller & Côté, 2012).

Compared to universities, colleges tend to play a less obvious, yet nonetheless important, role in knowledge generation. Colleges offer applied training programs and produce individuals with technical knowledge skills highly valued in the natural resources and manufacturing sectors. Colleges often have strong industry connections and applied research capabilities that help solve technical challenges encountered during production (Brzustowski, 2012; Conference Board of Canada, 2010).

Public research organizations conduct directed research in areas of science and technology (S&T) that align with federal or provincial S&T and innovation strategies; key public-sector functions (e.g., health, education, and security); or other areas of comparative research strength. For instance, in Canada, critical basic and applied research is conducted at the National Research Council, Defence Research and Development Canada, and Canadian Space Agency among others. Another example is *Fraunhofer-Gesellschaft*, Europe's largest public applied research organization. Of its annual budget of €1.8 billion, €1.5 billion is generated through contract research (from industry and the public sector), with the rest contributed by the German federal and Länder governments in the form of base funding (Fraunhofer IESE, 2013). Key areas of research include health, nutrition, and the environment; safety and security; information and communication; transportation and mobility; energy and living; and environmentally friendly production.

Governments at all levels generate knowledge, especially on the appropriate mix and design of efficacious public policies and delivery of efficient, timely, and high-quality public services. Some public services (e.g., health-care services) are among the most knowledge intensive and value added of all sectors. Governments also have crucial knowledge about the appropriate mix of direct and indirect policy and program support needed for innovation.

Firms generate and house various types of knowledge. Many large corporations (e.g., in information and communication technology (ICT) and pharmaceuticals) invest billions of dollars annually in research, development, and innovation activities. Established research firms generate streams of new knowledge to "keep their pipeline full" of potential new products, and established design firms generate knowledge in the form of incremental and process/marketing/organization innovations (Brzustowski, 2012). In addition, spinoff firms — groups of individuals seeking to commercialize a new idea emanating from basic or applied research conducted in universities or government labs — house codified knowledge in the form of a new product as their technology progresses from proof-of-concept to demonstration to early commercialization.

Perhaps even more important than these codified forms of knowledge is the wide-ranging tacit knowledge that resides in the intellectual and human capital of firm employees: leading-edge research knowledge (scientists and PhDs); engineering and other forms of technical knowledge (engineers and tradespersons); entrepreneurial, business, strategic, and financial knowledge (management); and other forms of "creative" knowledge. Established companies that base their business strategies on the transformation of R&D into innovation also have ongoing initiatives.

Indicators of Knowledge Generation

Table 3.1 provides a set of indicators that assess the state of knowledge generation in the innovation ecosystem. These indicators can be grouped in six broad classes:

- *HERD* and *BERD* – The most frequently cited indicators of spending on R&D and innovation in the academic and private sectors (higher education expenditure on R&D, HERD; business enterprise expenditure on R&D, BERD). While these indicators are a high-level measure of spending and do not contain information on what activities are supported, they are useful as general indicators of academic and private-sector commitment to research and innovation.
- *Publications* – An indicator of the stock of research knowledge — generated by universities, colleges, public research organizations, governments, and firms in a jurisdiction — that is published in peer-reviewed journals. It is often useful to collect data on the number of paper citations and journal impact to measure the quality of publications.
- *Patents* – An indicator of the stock of research knowledge with market potential generated by universities, colleges, public research organizations, governments, and firms in a jurisdiction.

- *Highly cited scientists* – An indicator of the extent to which a jurisdiction is at the cutting edge of the scientific frontier.
- *Stock of R&D personnel* – An indicator of the number of HQP engaged in R&D in the public and private sectors. Other potential measures of HQP quality could include years of employment and/or salary.
- *Degrees granted* – An indicator of the number of HQP in a jurisdiction.

In broad terms, these are indicators of the quantity and quality of knowledge generation activities conducted in the public (universities, colleges, public research organizations, governments) and private (firms) sectors. Some of these indicators were used in Council of Canadian Academies reports to assess the state of S&T (CCA, 2012b) and R&D (CCA, forthcoming) in Canada.

3.2 INNOVATION FACILITATION

Table 3.1
Indicators of Knowledge Generation

Knowledge Type	Selected Indicators
Public	Higher education expenditure on R&D (HERD) S&T outputs (publications and patents) Highly cited scientists Public-sector R&D personnel University graduates (PhD, master's, undergraduate) College graduates
Private	Business enterprise expenditure on R&D (BERD) R&D outputs (patents and publications) Skilled personnel including industry R&D personnel

Innovation is a complex and uncertain process. As such, the innovation activities of firms require sufficient risk and operating capital; strong business models; awareness of consumer preferences and global market opportunities; connections with networks of collaborators; and, as alluded to above, linkages to knowledge, whether public or private. In this sense, innovation is facilitated in two major ways: through financial support and networking capabilities.

The main justification for public funding of innovation activities, often R&D, is that since an innovation producer cannot appropriate all the benefits from its innovation investments — that is, so-called "knowledge spillovers" — it is likely to invest less in innovation than is socially optimal. It is argued that governments have a role in incentivizing innovation investment to correct this market failure by compensating for the gap between the private and social returns of innovation expenditure (Czarnitzki *et al.*, 2011). In practice, direct subsidies and indirect tax incentives are two key approaches to funding direct investments in innovation production. An extensive economics literature examines the relative merits of these approaches and offers empirical evidence of the factors that determine the most appropriate approach. The evidence is mixed on the effectiveness of these approaches (Mamuneas & Nadiri, 1996; Parsons & Phillips, 2007; Industry Canada, 2011a).

As discussed in Chapter 2, innovation intermediaries are a class of organizations that enable innovation by supporting the innovation activities of firms, or by enhancing national, regional, or sectoral innovative capacity (Dalziel, 2010). A wide variety of organizations may be classified as innovation intermediaries: university technology transfer offices, research networks, research institutes and councils, science parks, business incubators, industry associations, chambers of commerce, and economic development agencies. These organizations provide direct financial support, in-kind assistance of equipment and facilities for proof-of-concept and demonstration activities, and advice/mentoring.

Many new ventures face the significant challenge of securing sufficient start-up and risk capital (Industry Canada, 2011a). Conventional wisdom suggests that the cost of commercializing an idea is orders of magnitude more expensive than idea generation itself (Brzustowski, 2011). In Canada, many firms secure early-stage seed capital from the federally led Industrial Research Assistance Program. Since this funding support is often less generous than elsewhere (e.g., Small Business Innovation Research in the United States), individual (angel) investors and venture capitalists are essential. As a technology or business model progresses from proof-of-concept to demonstration to early commercialization and faces the so-called "valley of death" — the perilous pecuniary expanse that separates idea from innovation — angel investment and venture capital (VC) financing are critical for converting the fruits of R&D into economic value (CCA, 2009; Action Canada, 2011). In Canada, both aggregate VC investment and the number of firms receiving VC investment have been falling over the last decade (Institute for Competitiveness and Prosperity, 2011; CCA, 2009).

Universities are a source of spinoff firms that commercialize the ideas and inventions developed by faculty members and graduate students (Brzustowski, 2012). Most universities have dedicated technology transfer offices that help faculty members translate their ideas into commercially viable products. Other innovation intermediaries connect firms with sources of financing and individuals experienced in developing strong business models (e.g., finding customers; cultivating a market; learning accounting, finance, human resource, and operational skills; managing intellectual property; securing regulatory approvals; and developing a global mindset). They often organize conferences and seminars, and provide additional networking tools such as websites, directories, and newsletters (Brzustowski, 2012). Measuring the state of networking capabilities in an innovation ecosystem is more difficult than measuring financial support.

Indicators of Innovation Facilitation

Table 3.2 provides a set of indicators that assess the state of innovation facilitation in the innovation ecosystem. These indicators can be grouped in seven broad classes:

- *Direct financial support* – Indicators of direct financial support provided to firms by federal and provincial governments or innovation intermediaries. BERD categorized by funder offers a high-level overview of the source of these funds; however, it is more useful to examine sources of funding by program (see Chapter 2 for the portfolio of Ontario programs). At the program level, measures of the time required to approve a funding application are indicative of the internal efficiency of innovation programs.
- *Innovation intermediary in-kind support* – As discussed above, innovation intermediaries provide firms access to the research infrastructure (equipment and facilities) required during prototyping, proof-of-concept and demonstration activities, and to individuals with experience in developing business plans. Examining resource allocation within innovation intermediaries can collect measures of this type of support. It is also important, when possible, to examine the overhead of innovation intermediaries.
- *Private financial support* – Firms also receive direct financial support from angel and VC sources. An important metric is the ratio of this external support to internal firm resources (i.e., leveraged funds). In high-tech sectors, the magnitude of foreign direct investment can be a useful indicator.
- *Indirect financial support* – Measures of the magnitude of tax credit support for firm innovation.
- *Mentoring* – As discussed above, innovation intermediaries provide firms with mentoring, advice, and access to global networks and markets. This type of data is best collected through client-based surveys (Section 2.4.2).
- *Level of collaboration* – Whether financial, in-kind, or through networking, the degree of research and innovation collaboration between firms and other innovation agents (government, innovation intermediaries, or other firms) is an important measure of linkages in the innovation ecosystem. Public-private partnerships are especially important (Government of Canada, 2011).
- *New venture creation* – Critical outcome measures of the activities of innovation intermediaries in supporting researchers and firms are the number and magnitude of contracts, intellectual property (IP) agreements, and spinoff companies.

In broad terms, these are indicators of the quantity and quality of innovation facilitation activities, either financial or networking support. The validity of many of these metrics is discussed in Dalziel *et al.* (2012).

3.3 POLICY-MAKING

Table 3.2

Indicators of Innovation Facilitation

Facilitation Activity	Selected Indicators
Financial support	Business enterprise expenditure on R&D (BERD) (by funder) Innovation program direct business funding Application decision time Innovation intermediary in-kind assistance Innovation intermediary overhead Venture capital and angel funds Leveraged funds Foreign direct investment Tax credits
Networking capabilities	Mentoring/advice Access to global networks Level of collaboration (i.e., public-private) Contracts and intellectual property agreements; spinoffs

Policies and regulations play a critical role in supporting innovation. The previous two sections highlighted the importance of direct and indirect support for research and innovation to the effectiveness of the innovation ecosystem. The Panel has identified six additional types of government policies and regulations that can influence the health of the innovation ecosystem and the rate of firm innovation:

- *Competition policy* – Competition policy plays an important role in creating markets for innovative goods and services. Aghion *et al.* (2005) found robust evidence of an "inverted U-shaped" relationship between competition and innovation: greater competition first increases, and then decreases, the rate of innovation. The basic idea is that, on the one hand, firms have little incentive to innovate if they are not stimulated by competition — competition drives firms to stay ahead of their competitors by developing new and better products. On the other hand, with too much competition, firms are discouraged from innovating because the potential profits of innovation will be eroded through excess competition (CCA, 2009; OECD, 2009).
- *Trade policy* – Trade policies influence the innovative behaviour of firms by exposing them to global competition and large international markets. This is particularly important for technology-intensive industries (CCA, 2009).

- *Intellectual property* – IP policies enable firms to recoup their innovation investments by protecting their propriety rights. Consider, for instance, the pharmaceutical industry. Taking a new therapeutic or medical device to market can take up to 12 years as these products must go through three or four phases of clinical trials, often requiring more than a billion dollars of R&D (Brzustowski, 2011). If products make it to market, firms have only the remaining years of the initial 20 years of patent protection to recoup their R&D and marketing expenses, including the costs of development failures, and hopefully to generate profit before the market is flooded with generic versions (Brzustowski, 2011). In contrast to pharmaceuticals, IP is of less importance in ICT sectors where open innovation prevails in the case of platform technologies or first-to-market races that result in technology "lock-ins" (e.g., QWERTY keyboards) (Arthur, 2009).
- *Sector-specific regulations* – Regulations at the sectoral level can help create early markets for innovative products and services. Product standards, like smart labelling regulations, can enable well-informed consumer choices and influence market demand for innovative products. Environmental regulation plays a key role as a demand driver for firms that produce clean technologies, and as an impetus for producers of innovation to reduce their environmental impacts.
- *Good governance, transparency, and corruption* – The state of governance in a jurisdiction can be a critical determinant of the incentive for firm innovation. Governments that are transparent in their decision-making create a sense of security that the profits of firm innovation will not be appropriated through political and bureaucratic rent seeking.
- *Public innovation platforms* – To tackle ecosystem challenges, many governments have created innovation platforms, which can also be considered as small-scale ecosystems. An innovation platform is a needs-based network bringing together stakeholders from different interest groups, disciplines, sectors, and organizations to exchange knowledge, generate innovation, and develop joint action. Platforms create opportunities for stakeholders to test solutions to common problems. Box 3.1 provides three examples of public innovation platforms.

The Panel's review of the academic and public policy literature on policy-making did not reveal a set of ready-made indicators of policy-making. As will be discussed in Chapter 4, this requires a benchmarking exercise.

3.4 DEMAND

The needs and preferences of consumers are increasingly driving business innovation (von Hippel, 2005). For most of the last century, innovation was largely supply driven, with firms, rather than consumers, dictating the types of products produced. As such, demand (output valued by consumers and society) was ex-post

Box 3.1
Public Innovation Platforms

United Kingdom

The United Kingdom Technology Strategy Board launched the Low Carbon Vehicles Innovation Platform in 2007. This platform has two main goals: to support U.K.-based firms in accessing the rapidly developing low carbon vehicles market; and to accelerate the adoption of low carbon vehicles by consumers (Technology Strategy Board, 2013). U.K. policy-makers believe that both growing demand from customers and pressure from regulators will create new business opportunities from both established firms and innovative new entrants (Technology Strategy Board, 2013; PACEC, 2013). A key element of the platform is the Low Carbon Vehicles Integrated Delivery Program, which receives approximately £250 million of joint government and industry investment. (Technology Strategy Board, 2013). This program supports the development of low carbon vehicles from initial research through to proof of concept and demonstration. In 2009, a competition to create a large-scale, ultra-low carbon vehicle demonstration program was launched; with eight U.K. consortia comprised car manufacturers, power companies, universities, and local governments of participating. This has resulted in around 340 vehicles undergoing road trials (Technology Strategy Board, 2013).

European Union

The Eco-innovation Platform (Eco-IP) was established by Europe INNOVA to accelerate the diffusion of eco-innovation solutions across firms. Fundamentally, the Eco-IP attempts to align the demand and supply of environmentally-friendly processes and practices, thereby helping develop innovative eco-industries in Europe (Europe INNOVA, 2013). The initiative supports the development and testing of "new or better innovation support mechanisms for innovative small and medium-sized enterprises (SMEs), particularly in technological and industrial fields" (Europe INNOVA, 2013). Bringing together public and private partners from a host of countries interested in developing new forms of support for innovation, Eco-IP considers both the needs of specific companies already holding eco-innovative solutions and the role these can play in support of wider social goals (Europe INNOVA, 2013). The Eco-IP helps support the innovation capacity of firms in four sectors identified by European Union Lead Market Initiative and the Environmental Technologies Action Plan (ETAP): bio-based products, water and wastewater, recycling and resource efficiency, and food (Europe INNOVA, 2013).

continued on next page

Sweden

The New Karolinska Solna University Hospital in Sweden, which is due to open in 2016, is possibly the largest European public-private contract ever with an investment of over €5 billion (Stockholm County Council, 2012). Upon completion, the hospital will be a central health innovation hub in Northern Europe, meeting research and education needs. Intended as a platform for innovation, it has established the Innovation Place Karolinska to promote collaboration in medical technology between industry, education, and the health-care sector (Stockholm County Council, 2012).

driven by creative and clever marketing campaigns. With developments in analysis of consumer data over the last decade, however, firms are now better able to track consumption patterns and assess consumer preferences. Some firms use platforms so that consumers can design and configure products they wish to purchase. In this sense, consumers are more than just a target market for innovations — they are the innovators themselves. As von Hippel (2005) argues, innovation is being "democratized." Some public administrations use modern technologies to allow citizens to use, develop, and increase productivity of public services. It follows that demand may originate in individual consumers, the public sector (public procurement), or other firms in the global value chain (von Hippel, 2005).

Public procurement is an important lever to spur innovation. It can be a major part of domestic demand, with government, as a single user with sufficient purchasing power to constitute a market on its own, acting as a lead user to initiate creation of lead markets (Edler & Georghiou, 2007). This makes possible early adoption of new innovative products or services so that they become widespread and dominant in the market. Public procurement may also help overcome a range of market and system failures on the demand side — in areas like education, health, and the environment. In this sense, public procurement has the potential to improve public services in general. In its efforts to satisfy new societal needs (e.g., sustainability, energy efficiency, etc.), the state may demand innovative solutions more often than private consumers (Edler & Georghiou, 2007).

Public procurement can take several forms: general procurement versus strategic procurement, direct public procurement versus catalytic procurement, and commercial versus pre-commercial procurement (Edler, 2007). General procurement is when innovation serves as a criterion for public tendering; strategic procurement is when demand for a certain technology is encouraged to stimulate the market for that technology. Direct public procurement is when goods or services are exclusively for public use; catalytic procurement is when a government the state initiates the procurement, with the procured products used exclusively by private-sector users. Pre-commercial procurement, rather than commercial procurement, occurs when a government purchases products which require further R&D, thereby helping to share risk between supplier and procurer (Edler, 2007).

In a 2003 report to the European Commission, over 50 per cent of the 1,000 firms surveyed indicated that demand is the main source of innovations, while only 12 per cent considered new technological developments in firms as the major driver (Business Decisions Limited, 2003). Using survey data from the SFINNO database on commercialized innovation between 1984 and 1998, Palmberg (2004) showed that the success of 48 per cent of innovation projects in Finland during the period were triggered by public procurement or regulation. In Canada, given the little attention paid to public procurement as innovation policy, no study has been done to date on the impact of public procurement in fostering innovation. Since studies in other jurisdictions — as shown above — have indicated that public procurement has an important role to play in fostering innovation, this has prompted a recommendation from the Jenkins panel report to "make business innovation as one of the core objectives of procurement" (Industry Canada, 2011a).

Regulation can often be viewed as a demand-driven innovation policy. Regulations are used to promote the emergence and diffusion of innovations, by stimulating demand and creating the conditions for their early adoption. This raises the competitiveness of companies by creating markets for innovative solutions (e.g., for new health or energy technology), and/or by reducing the risks of commercialization by speeding up market entry. It also helps meet a range of broad societal challenges such as climate change, efficient energy supply, environmentally sustainable products, and higher-quality and more efficient health services (whether private or public).

Outside of government expenditure on public procurement, there are no readily available direct indicators of market demand. As with policy-making, this requires a benchmarking exercise.

3.5 FIRM INNOVATION

Firms are the central actors that produce innovation in an innovation ecosystem (OECD, 2009). In advanced economies, firms commercialize new products and processes, and use new marketing and organizational methods to create markets and move down global value chains (CCA, 2009). While the Panel acknowledges that other important forms of innovation take place outside of the business sector (in the public and social sectors),[10] business innovation is:

- at the core of economic competitiveness;
- a critical means to circumvent resource scarcity;
- an essential tool to tackle emerging challenges at regional, national, and global levels; and
- the fundamental mechanism to raise standards of living.

Understanding the key characteristics of firms that govern how they are influenced by the innovation ecosystem is critical. Firms use the outputs of the first four aggregate behaviours as inputs for production and innovation. The economics, management, and policy literature commonly categorizes firms according to characteristics that are most salient to innovation (e.g., size, age, sector, region, supply chain location export orientation, etc.). In particular, the Panel believes that size, maturity (new or established), and economic sector are the most salient characteristics of innovative firms. Firm taxonomies can be useful to organize firms according to these categories (Brzustowski, 2012; Miller & Côté, 2012).

Recall the production function presented in Section 2.5.3. This model is based on the premise that firms aim to earn profit by using innovation ecosystem resources (physical, financial, and R&D capital; and labour) to produce products with market potential. In doing so, firms have both direct (e.g., GDP; new products, markets, and exports; employment) and indirect (e.g., taxes, entrepreneurship) economic impacts. Not all innovation investments, however, are created equal. Different investments provide different resources for different firm activities, which then produce different economic and social impacts. In both Ontario and Canada, most investments flow indirectly to firms through conduit actors like universities, innovation intermediaries, and governments, which, through their own activities, supply the above inputs to firm innovation. These inputs are more or less critical depending on firm activity. For instance, start-up firms are heavily reliant on specialized financial tools (e.g., angel investment, venture capital); but more mature firms are more reliant on labour inputs to conduct R&D and develop innovative forms of production, organization, and marketing (Brzustowski, 2012). In assessing bottlenecks in an innovation ecosystem and leverage points for public investment, the central task is to judge the distribution of firms and how investments influence firm activities. Investments can then be made in the aggregate level behaviours that provide these resources.

10 Baldwin and Gu (2009) discuss the methodological issues that prevent Statistics Canada from measuring public and social (non-market) sector productivity (innovation).

In more specific terms, the genesis of a new venture fundamentally rests in a novel idea or invention with commercial potential. Ideas can translate into the genesis of a new venture in two main ways. The first, and arguably the most important, is through HQP trained in universities, colleges, public research organizations, and industry (Miller & Côté, 2012). These individuals, whether scientists, engineers, management, or other professionals, translate research findings, engage in development activities, and supply the business acumen needed to assess market demand and commercialize ideas. Depending on the industry, intellectual property rights in universities and innovation intermediaries, and at the economy-wide level, often play a key role (Jaffe & Lerner, 2006).

Second, ideas are translated into start-up ventures through the activities of the inventor, sometimes with the support of the activities of innovation intermediaries. This can be in the form of royalty agreements or licenses granted to existing firms, university spinoffs, public-private partnerships, and other forms of networking. It is simply not adequate to measure the primary outputs of knowledge generation (i.e., publication and patents) and assume these ideas have been effectively translated into something with commercial potential. What should be measured are the makeup of HQP and the outcomes of the commercial activities of intermediaries.

It is often remarked that Canada and Ontario are hotbeds of great ideas and people, but the financial capital available to seed and develop new ventures is severely lacking (CCA, 2009). While considerable financial innovation investments are made in universities and public research organizations (i.e., in knowledge generation), there is a dearth of innovation investments in firms themselves. These investments are considered essential in enabling firms to cross the valley of death (Industry Canada, 2011a). Venture capital is scarce in this valley because of the uncertainty associated with early products, inexperienced management, and unsecured markets, which makes it challenging for investors to evaluate the potential return on their investments (Brzustowski, 2012). In the United States, the Small Business Innovation Research program provides direct funding and public procurement support to start-up firms (owned by U.S. citizens) in the stages that roughly coincide with the valley of death. Although this program is widely regarded as a hallmark start-up funding program (Lerner, 1999), the evidence is mixed (Wallsten, 2000).

In general, financial capital comes from four sources: the inventor's personal finances (sometimes even backed by home equity), angel investors and venture capitalists, innovation intermediaries, and direct government support programs. While the last three sources are regarded as deficient in the Ontario context (Miller & Côté, 2012), measuring their magnitude is straightforward.

With a commercially relevant idea and sufficient seed and development capital, firms engage in initial production activities, which span from prototyping, proof-of-concept and demonstration, to commercial validation and early marketing efforts. The training of HQP, both technical and non-technical, is especially important as these individuals conduct R&D, incrementally innovate, learn, develop business plans, assess market demand and public procurement objectives, and physically produce products. Entrepreneurship is essential in creating a commercially viable new venture that survives to grow and mature.

As firms grow and mature by expanding production, they require additional labour resources. These individuals engage in the following activities:

- creating new intellectual property;
- developing new products and further refining existing products through R&D, incremental innovation, and learning-by-doing;
- acquiring financial capital and developing market strategies/assessing market demand; and
- physically producing products through general labour efforts.

These activities are conducted by individuals trained in universities and public research organizations — scientists, engineers, and management professionals — and by individuals with complementary skills learned in colleges or developed in the secondary education system. Both inputs, skilled and unskilled labour, are easily measurable by examining the employment makeup of firms. Statistics Canada uses a more sophisticated measurement: labour composition is a measure of the growth of labour quality, estimated by aggregating across 112 classes of workers (gender, seven age groups, four education levels, and two employment categories), and applying wage weights to each class.

Firms also use physical capital. Innovation intermediaries provide research infrastructure and platforms, and governments support acquisition through direct business subsidies. Physical capital used by firms may be measured according to the capital deepening methodology of Statistics Canada. This is estimated by aggregating across 28 asset classes, and applying the user cost of capital weights to each class, which incorporates market return, depreciation, and taxation

(CCA, 2009). Firms also use both internal and external intangible capital, which are most often measured by the stock of R&D in a firm and in the industry or jurisdiction, respectively. R&D activities are supported by the knowledge transfer and networking activities of innovation intermediaries, and indirectly by tax credits.

Indicators of Firm Innovation

Table 3.3 provides a set of indicators that assess the state of firm innovation in the innovation ecosystem:

- *Rate of new venture creation* – The rate and number of new ventures, especially in the high-tech sector (e.g., ICT, biotechnology, clean technology, nanotechnology, etc.), are indicators of the effectiveness of the innovation ecosystem in fostering firm innovation. The distribution of firms by type (e.g., according to the typologies indicated in Brzustowski (2012) or Miller and Côté (2012)) likely reflects the strengths and bottlenecks in the innovation ecosystem (i.e., different types of firms use different types of resources from the ecosystem). The creation of innovative firms can have important economic spinoff effects for the economy. For instance, Moretti (2012) estimates that one job created in the high-tech sector leads to the creation of five jobs in the services sector.
- *Leading R&D firms* – Leading R&D and innovation companies function as "anchor" firms for smaller specialized suppliers, often enabling the development of local clusters by attracting other firms/talent and fostering linkages. For example, both Nortel Networks and BlackBerry were instrumental in the development of Ottawa and Waterloo technology clusters.
- *New and improved products* – This is a direct indicator of the fruits of firm innovation. These data are generally collected in innovation surveys.
- *Aggregate productivity* – The leading indicator of firm innovation, aggregate productivity is a measure of the output produced per hour worked (labour productivity) or the portion of output that cannot be accounted for by the contributions of labour and capital (multifactor productivity). This can be measured at the firm level using the CDM model, or at the economy level using growth accounting.
- *GDP* – The share and rate of GDP growth, especially in high-tech sectors, is an important indicator of the ultimate impact of investments in innovation.

Table 3.3

Indicators of Firm Innovation

Selected Indicators	
• Rate of new venture creation • Leading R&D firms • New or improved products	• Aggregate productivity • GDP

3.6 PUBLIC-SECTOR AND SOCIAL INNOVATION

While public-sector innovation and social innovation are not considered in the Panel's firm-centric innovation ecosystem framework, they warrant a brief discussion.

Public-sector Innovation

Public-sector innovation — the creation and implementation of new processes, services, and policies that result in significant improvements in the efficiency, effectiveness, and quality of outcomes — may occur across a wide variety of public-sector entities: from policy development to program delivery, from regulatory approaches to technology uses, and from organizational arrangements to provision of new or enhanced services.

Over the past century, the public sector has been the source of many innovations that have enhanced the quality of public services and generated enormous social impact (e.g., in the areas of the welfare state (Nasar, 2011), public health insurance, microfinance, etc.). In most advanced economies, the public sector faces increasing pressure to deliver higher-quality and lower-cost public health, education, and social services to a growing user community. Many public services (e.g., health care) are among the most knowledge-intensive sectors of the economy (CAHS, 2009), and thus have huge potential for innovation. The public sector is also generally considered a key player in addressing large-scale social and environmental problems. Four examples of public-sector innovation are considered in Box 3.2.

The larger the public sector, the more critical is the need to deliver high-quality services and low costs. In Europe, for example, the public sector comprises about 45 per cent of EU GDP and 15 per cent of total employment (PRO INNO Europe, 2012b). Public procurement is a critical lever by which the European Union addresses social issues, and constitutes 17 per cent of GDP (PRO INNO Europe, 2012b). Given the size of the European public sector, it follows that there is an essential need for efficiency gains, better governance, and more user involvement in the delivery of public services (PRO INNO Europe, 2012b). While the public sector only accounts for 22 per cent and 18 per cent of GDP in Canada and Ontario, respectively, the need for public-sector innovation is no less critical (Nicholson, 2012). As mentioned in Chapter 2, the recent Commission on the Reform of Ontario's Public Services was tasked with developing recommendations to increase the efficiency of the public sector — that is, to foster public-sector innovation:

Box 3.2
Public-sector Innovation

Denmark

The Danish e-government health strategy — *Towards Better Digital Service, Increased Efficiency and Stronger Collaboration* — resulted in the establishment of an e-health initiative agreed upon by the state, regions, and municipalities (Denmark, 2007). In addition, a fund for assistive technology was created for 2009-2015 to co-finance investments in projects using labour saving technologies in the public sector, and to adopt innovative ways of working in, and structuring, public organizations. To reach out to the most vulnerable segments of the population and ensure the most efficient and effective use of public resources, the government focused on optimizing the impact of e-government on public-sector reform, strengthening the organizational structure and arrangements for e-government development and implementation, increasing user take-up, and fundamentally securing the benefits of e-government projects.

Sweden

The Swedish Governmental Agency for Innovation Systems (VINNOVA) has established a funding program for new, innovative health-care solutions to meet the challenges of Sweden's rapidly expanding proportion of elderly citizens. It has identified several key areas: health and social care services; the link between health, climate, and the environment; and the health-care sector as a production system. The program will run until the end of 2013 with a total budget of around Kr 600 million ($89 million) (Andreasson & Winge, 2010). It looks ahead to 2014–2025 to identify future needs: breakthroughs in prevention, diagnosis, treatment, and care of disease; demarcations of future patients, users, and customers; potential new, innovative projects and services; and global market projections for health-sector services.

Sure Start is a multidimensional U.K. program that combines the delivery of childcare, early education, and health and family support. Beginning in 1999, Sure Start aims to improve the health and well-being of disadvantage children by supporting low income families with children under four years old (Johnson, 2011). It is based on the observed demand for early childhood health and education services across low income families. To date, the evidence is mixed on its effectiveness (Johnson, 2011).

> We can perhaps shoot for a grander goal — a province that provides the best public services, delivered in the most efficient manner, in the world. If this sounds impossibly ambitious, put the question another way: Why not? We goad our business sector to win new customers globally in the face of stiff competition. Why not apply the same standards to our government? Why not give our public servants an objective that can turn the task of transformation — which will at times be a very tough slog — into a project that becomes a source of real pride?
>
> (Commission on the Reform of Ontario's Public Services, 2012)

Public-sector innovation, however, is difficult to achieve (Nicholson, 2012). Governments are generally large and complex; as such, a wide range of actors conducts their activities. There are often problems with the widespread coordination of activities and in understanding the unknown consequences of changes to the status quo. It follows that some governments and departments are subject to inertia and over-bureaucratization. A fundamental feature of most public-sector organizations is the lack of a market — thus little competition exists to spur innovation and improvements in service delivery. It is therefore essential to articulate the objectives of public-sector organizations, and ascertain the incentives and disincentives that underpin innovation. These factors range from changes in government policy, end-user demands, and developments in technology to agencies and individuals seeing opportunities to improve the way they work (Nicholson, 2012).

Fundamentally, without public-sector investment in changes in service delivery, it may not be possible to adopt innovations from firms producing products and processes in areas such as health, education, and the environment. New technologies from the private sector often require changes to the way the public sector delivers services. Equally, such private-sector-produced innovations may enable desired improvements in public-sector efficiency and effectiveness. The manner in which the public sector makes decisions about the technologies it adopts has major implications for innovation. Consider, for instance, concerns that the emphasis on cost effectiveness of new drugs may be reducing the willingness of pharmaceutical firms to invest in R&D for new products, which initially may not be cost effective. Ultimately, the public sector does not operate, invest, or innovate in isolation.

Assessing the impact of public-sector innovation requires an understanding of how the public sector structures, organizes, and promotes its own innovation. While this is relatively well understood in the private sector, similar information on public-sector innovation is limited, and quantitative data are lacking (Nesta, 2011d). As part of its European Innovation Scoreboard, the European Commission is currently piloting the European Public Sector Innovation Scoreboard (EPSIS), a leading approach to identifying potential indicators (PRO INNO Europe, 2012b).

Social Innovation

Public-sector innovation can be distinguished from social innovation — a form of innovation targeted at supporting, developing, and enhancing the lives of the most marginalized, disenfranchised, and vulnerable populations, groups, and individuals in society. Social innovation delivers new services that improve the quality of life of individuals and communities, and implements new labour market integration processes that enhance the position of individuals in the labour market. It is not simply about introducing products and processes, but rather about satisfying end users' *needs* and fostering their labour market potential. Various definitions of social innovation (OECD, 2010c; Canadian Task Force on Social Finance, 2010) have overlapping meanings depending on the social purpose (e.g., microfinance, distance learning, etc.) or social process (e.g., open innovation). Social innovation can take place in the private, public, or not-for-profit (third) sectors, with platforms needed to facilitate cross-sector collaborative social innovation.

3.7 CONCLUSION

This chapter has developed the Panel's framework for assessing the impact of innovation investments. The firm-centric innovation ecosystem approach combines five aggregate behaviours to demonstrate how the state of these behaviours — which can be assessed by examining indicators — determines the effectiveness of the ecosystem in generating innovation, and ultimately impact. From this perspective, the impact of innovation investments is best understood by assessing their overall effect on the state or health of the innovation ecosystem.

The firm-centric innovation ecosystem is an approach to assessment, rather than to measurement. The framework captures the non-linear and dynamic nature of innovation by examining aggregate behaviours, which enables assessment to eschew the complicated relationships between innovation actors at the micro level. The measurement methodologies presented in Chapter 2, which can provide robust and reliable estimates of impact at the program level, and the indicators discussed in this chapter, are best considered in the context of the ecosystem. Just as the health of a human body can be assessed by examining discrete measurements and indicators of health (e.g., blood pressure, cholesterol level, body fat percentage, etc.), the health of the innovation ecosystem can be assessed through discrete measurements of impact. Assessing the state of the innovation ecosystem complements measurement by:

- organizing impact measurements and existing indicators;
- identifying the need for greater data collection; and
- highlighting the need for qualitative analysis.

The next chapter examines how program impact measurement and innovation ecosystem assessment can be applied to evaluate the state of the Ontario innovation ecosystem.

4

Evaluating the Ontario Innovation Ecosystem

- Ontario Investments in the Innovation Ecosystem
- Evaluating the State of the Ontario Innovation Ecosystem — Scorecard Approach
- Evaluating the State of the Ontario Innovation Ecosystem — Qualitative Analysis
- Conclusion

4 Evaluating the Ontario Innovation Ecosystem

Key Messages

- Assessing the state of the five aggregate behaviours — knowledge generation, innovation facilitation, policy-making, demand, and firm innovation — of the Panel's firm-centric innovation ecosystem framework requires combining program impact measurements and indicators.
- Comparing measurements and indicators over time or across jurisdictions can develop a scorecard. This is a quantitative evaluation of the state of the innovation ecosystem.
- Developing an Ontario innovation scorecard that fully reflects the Panel's firm-centric innovation ecosystem framework is currently not feasible because of insufficient data.
- Applying this approach requires the Government of Ontario to build program impact measurement directly into innovation support programs; collect more indicators of the five aggregate behaviours, based on data from repeated cross-sectional observations and longitudinal data; and conduct benchmarking exercises of policy-making and demand.
- Examining past attempts to measure the impact of innovation investments in Ontario allows partial identification of areas of strength. In this sense, scorecards reside on a continuum, with the Panel's firm-centric innovation ecosystem approach as the best practice and previous scorecards as the best accomplished to date.
- Quantitative approaches can often miss important contextual features of an innovation ecosystem. As such, qualitative methods — case studies, surveys, and independent innovation ecosystem evaluations — should complement quantitative approaches to innovation ecosystem assessment.

The preceding two chapters presented methodologies to measure the impact of innovation support programs (Chapter 2) and the firm-centric innovation ecosystem framework designed to assess the state of the innovation ecosystem (Chapter 3). The basic idea is that program impact measurements and indicators are best organized around the five aggregate behaviours — knowledge generation, innovation facilitation, policy-making, demand, and firm innovation — that comprise the innovation ecosystem. The state of these behaviours, as implied

> "The only person who acts sensibly is my tailor. He takes my measure anew every time he sees me. Everyone else goes by their old measurements."
>
> George Bernard Shaw

through measurements and the resulting indicators, provides an assessment of the potential effectiveness of the innovation ecosystem in generating innovation and impact.

The firm-centric innovation ecosystem approach to impact assessment recasts what can be understood as innovation investments. While many investments are financial in nature (e.g., higher education expenditure on R&D (HERD), business enterprise expenditure on R&D (BERD), venture capital, etc.), this approach highlights the importance of non-pecuniary investments (e.g., restructuring of public research organizations and innovation intermediaries, changing funding eligibility requirements and targets, shifting public policies, etc.). Although investments are made in actors at the micro level, the ultimate impact of an investment must be examined on the basis of its influence on the health of the innovation ecosystem. In this sense, each investment alters the state of the ecosystem, and it follows that an investment may not have the same impact today as tomorrow. As the epigraph suggests, it is critical to mimic Shaw's tailor — measure each innovation investment "anew" in accordance with the state of the innovation ecosystem.

This chapter explores how the Panel's firm-centric innovation ecosystem approach to impact assessment can be applied in the Ontario context. It demonstrates how program-level impact measurements and indicators can be used to assess the state of the five aggregate behaviours. In doing so, it discusses how to construct an Ontario innovation scorecard that provides a quantitative evaluation of the innovation ecosystem and highlights how areas of strength in innovation or innovation support can be assessed. This exercise also shows that more data are needed to develop a scorecard that adequately captures the full extent of the Ontario innovation ecosystem. As such, the Government of Ontario could collect new data and constantly monitor the state of the innovation ecosystem. This latter task requires a qualitative assessment — an approach currently undertaken in leading European jurisdictions and organizations.

4.1 ONTARIO INVESTMENTS IN THE INNOVATION ECOSYSTEM

Chapter 2 classified Ontario innovation support programs into six classes: direct academic support, public and not-for-profit research organizations, innovation intermediaries, direct business support, indirect business support, and public procurement. In the context of the firm-centric innovation ecosystem, these programs can be reclassified according to which aggregate behaviour they support. As shown in Table 4.1, these funding programs primarily support knowledge generation and innovation facilitation. This classification reveals the difficulty of assessing whether Ontario innovation investments support policy-making and demand. The next section examines the state of these four behaviours, along with the fifth behaviour, firm innovation, and suggests how a scorecard could be developed for the Ontario innovation ecosystem.

Table 4.1

Ontario Innovation Investment Programs by Behaviour

Aggregate Behaviour	Program Type	Investment Programs
Knowledge Generation	Direct academic support	Ontario Research Fund (Research Excellence and Research Infrastructure) Early Researchers Award Post-doctoral Fellowship International Strategic Opportunities Program OMAFRA-University of Guelph Research Partnership
	Public and not-for-profit research organizations	Ontario Institute for Cancer Research Ontario Brain Institute Perimeter Institute for Theoretical Physics Agricultural Research Institute of Ontario Ontario Forest Research Institute
Innovation Facilitation	Innovation intermediaries	Ontario Network of Excellence • Ontario Centres of Excellence • MaRS • Regional Innovation Centres Business Ecosystem Support Fund Health Technology Exchange Agri-Technology Commercialization Centre Centre for Research and Innovation in the Bio-economy Water Technologies Acceleration Project
	Direct business support	Ontario Venture Capital Fund Ontario Emerging Technologies Fund Innovation Demonstration Fund Market Readiness Program Investment Accelerator Fund Life Sciences Commercialization Strategy Business Mentorship and Entrepreneurship Program Biopharmaceutical Investment Program
	Indirect business support	Ontario Innovation Tax Credit Ontario Business Research Institute Tax Credit Ontario Research and Development Tax Credit Ontario Interactive Digital Media Tax Credit Ontario Tax Exemption for Commercialization
Policy-making	n/a	
Demand	Public procurement	Green Focus on Innovation and Technology Green Schools Pilot Initiative

4.2 EVALUATING THE STATE OF THE ONTARIO INNOVATION ECOSYSTEM — SCORECARD APPROACH

The use of a scorecard to assess the state of innovation is a widespread practice. The OECD annually publishes the Science, Technology and Industry Scoreboard, which provides comparative data on OECD countries. The European Commission publishes Global and European Innovation Scoreboards, which are the main tools for innovation assessment and a key source of comparative data. As discussed in Section 2.5.2, scorecards have been developed for the Alberta and Quebec governments, and MRI. Developing a scorecard requires combining impact measurements and indicators of the state of the aggregate behaviours into a single framework, and comparing them over time or to other jurisdictions. This means combining program impact estimates (Chapter 2) with suggested indicators of behaviours (Chapter 3) to provide the data specifications needed to develop a comprehensive Ontario scorecard.

The State of Knowledge Generation in Ontario

Recall Table 2.4, which suggests that knowledge generation investments (direct academic support and public and not-for-profit research organizations) would be better evaluated by regression discontinuity design (RDD; see Section 2.5.4). Consider programs like the Ontario Research Fund or the Ontario Institute for Cancer Research. Funding proposals could be evaluated and ranked according to a pre-specified set of criteria, with only those proposals above a pre-specified threshold funded. Then, by comparing those individuals just above and just below the threshold, robust estimates of program impact could be achieved. This would be a direct measurement of the impact of knowledge generation support in Ontario.

Recall Table 3.1, which provides suggested indicators of the state of knowledge generation. Many of these indicators have been collected for Ontario:

- *HERD* and *BERD* – In 2010, although fourth among Canadian provinces in HERD intensity (0.78 per cent of GDP), Ontario outstripped the OECD average of 0.55 per cent. Ontario's 2009 BERD intensity (1.20 per cent) exceeded the Canadian average (0.99 per cent), but trailed Quebec (1.50 per cent) and the OECD average (1.62 per cent) (Statistics Canada, 2012).
- *Publications* – During the 2005–2009 period, Ontario produced close to 20,000 papers, which were cited 4.1 times on average in 2008. Ontario compares favourably to Massachusetts (approximately 25,000 papers) in total papers, and ranks second to British Columbia (4.3) in average citations (Government of Ontario, 2010a).

- *Patents* – Ontario leads all Canadian provinces in number of patents filed, but trails well behind leading jurisdictions like Massachusetts and California in patents per million people (Government of Ontario, 2010a).
- *Highly cited scientists* – In 2007, Ontario had some 90 "star" scientists who were among the 250 mostly highly cited in their respective fields. Approximately one-third of these scientists were in ecology and the environment, plant and animal sciences, and agricultural sciences (Government of Ontario, 2010).
- *Stock of R&D personnel* – In 2007 Ontario, with 2.6 R&D personnel per 1,000 people, trailed only Quebec (2.7) (CCA, forthcoming). These figures include individuals in higher education (universities and colleges) and public research institutes. In 2009, Ontario firms employed approximately 72,000 R&D personnel, the most of any Canadian province. In personnel per thousand persons, Ontario (5.5) slightly trailed Quebec (6.5). The ratio of BERD-to-personnel, which potentially measures the degree to which personnel are used, was approximately $100,000, slightly ahead of Quebec ($90,000), but vastly trailing Alberta ($170,000) (CCA, forthcoming).
- *Degrees granted* – Ontario granted some 80,000 undergraduate and 12,000 graduate degrees in 2008. The distribution of degrees is heavily skewed towards social and behavioural sciences, and business, management, and public affairs. While Ontario outperforms other Canadian provinces, it still lags leading jurisdictions (e.g., Massachusetts and Israel) in degrees per capita (Government of Ontario, 2010a).

Overall, sufficient data have been collected to develop a scorecard section for knowledge generation.

The State of Innovation Facilitation in Ontario

Recall Table 2.4, which suggests that innovation facilitation support programs would be better evaluated by random field experiments or matching estimation (for innovation intermediaries and direct business support), and by regression discontinuity design or difference-in-difference estimation (for indirect business support) (see Section 2.5.4 for a detailed discussion of these approaches). As described above, if all innovation facilitation investments were evaluated by econometric program evaluation methods, they could be compared to each other or over time. This would be a direct measurement of the impact of innovation facilitation support in Ontario.

Recall Table 3.2, which provides suggested indicators of the state of innovation facilitation. The majority of these indicators have not been collected for Ontario. A review of the academic and public policy literature, however, reveals that Ontario performs moderately well in innovation facilitation. The much maligned valley of death phenomena (CCA, 2009; Action Canada, 2011; Brzustowski, 2012; Miller & Côté, 2012) in Ontario (and Canada) seems to suggest that early-stage firms are not receiving the necessary resources to cross this hazardous expanse. This is, of course, best assessed by econometric program evaluation methods.

In comparison with key U.S. states, Ontario performs relatively poorly in technology transfer (Government of Ontario, 2010a). This is in keeping with the general criticisms of innovation intermediaries in Canada, relative to other jurisdictions (CCA, 2009). Ontario intermediaries, however, compare favourably with those in other provinces (Government of Ontario, 2010a):

- Over the 1998–2009 period, Ontario outperformed other Canadian provinces, both in total ($1.8 billion) and share of total as a percentage of population (120 per cent) of research infrastructure funding from the Canada Foundation for Innovation.
- Ontario vastly outpaced other Canadian provinces with nearly $400 million in industry-sponsored research in 2008 compared to $125 million in Quebec.
- Ontario outperformed other provinces in invention disclosures, patent filings, and number of start-ups.
- Ontario trailed only Quebec in gross licensing income and number of licenses from universities and research hospitals in 2008: $22 million to $17 million and 404 to 363, respectively.

Despite a severe shortage of venture capital (VC) financing both in Ontario and in Canada, Ontario has outpaced other provinces in VC financing (Institute for Competitiveness and Prosperity, 2011). In 2007, of the $2.1 billion invested in 412 Canadian firms, approximately 46 per cent ($952 million) went to Ontario. Ontario captured an even larger portion of major VC investment, with 63 per cent of the top 10 deals in 2007. In general, this investment was largely in high-tech industries, with 50 per cent in information and communications technologies (ICT) firms and 30 per cent in life sciences firms. Perhaps not surprisingly, given the noted sparseness of Canadian VC, foreign investment comprised a large share, 53 per cent ($513 million), of total funding in 2007. Although trailing the leading jurisdictions of California and Massachusetts in VC investment as a percentage of GDP, Ontario performs comparably with the median of 16 North American peer jurisdictions identified by the Institute for Competitiveness and Prosperity (2011). For all these jurisdictions, including Ontario, VC investment has been falling in recent years as a result of sub-par returns (Institute for Competitiveness and Prosperity, 2011).

Angel investors are another important source of private funding support of innovation. The significant decline in VC investment in Canada in recent years has opened the start-up investment market to angel investors (Institute for Competitiveness and Prosperity, 2011). These investors, often wealthy individuals, personally finance the same high-risk, high-growth start-ups as venture capitalists. Previously dominated by fragmented individual investors, the angel market is changing as organized business angel groups play an increasingly prominent role. Organized angel groups in Ontario include Cleantech Angel Network (Toronto), Infusion Angels (Waterloo), Purple Angel (Ottawa), Southwestern Ontario Angel Group (London), and York Angels (Vaughan). A recent National Angel Capital Organization (NACO) study (2011) surveyed a number of Canadian angel groups to examine the activity levels of angel investment in Canada in 2010. The study found the following:

- The majority of angel investments (61 per cent) were in Ontario, followed by British Columbia (16 per cent).
- The magnitude of angel investments in a single deal ranged from less than $50,000 to over $5 million, with most investments ranging from $100,000 to $1 million.
- Angels invested in a wide range of Ontario industries, with the biggest concentration in the ICT sector (43 per cent), followed by life sciences (18 per cent) and clean technology (16 per cent).

Overall, insufficient data have been collected to develop a scorecard section for innovation facilitation.

The State of Policy-making in Ontario

As discussed in Section 3.3, there are no ready-made indicators of the state of policy-making. In contrast with knowledge generation and innovation facilitation, assessing the state of policy-making requires a benchmarking exercise, in which policies in a jurisdiction are qualitatively compared with those in other reference jurisdictions. Based on its collective experience, the Panel determined that this requires not only examining policy and legislative documentation, but also interviewing individuals responsible for developing innovation policy in various jurisdictions. In some instances, if a public policy is introduced that affects some individuals or firms and not others, difference-in-difference estimation can be used to obtain rigorous and reliable estimates of impact (see Section 2.5.4).

The State of Demand in Ontario

The Government of Ontario invests in demand in two ways. First, the public procurement of products that enable the delivery of key public services can potentially create an enormous source of demand for innovative firms in Ontario.

Public health and education comprise approximately 40 per cent ($44.8 billion or 6.9 per cent of GDP) and 20 per cent ($20.4 billion or 3.5 per cent of GDP) of Ontario government expenditure, respectively (Commission on the Reform of Ontario's Public Service, 2012). Both the Drummond (Commission on the Reform of Ontario's Public Service, 2012) and Jenkins (Industry Canada, 2011a) reports remarked on the potential for public procurement to spur innovation. Two public procurement programs focus on innovation: Green Focus on Innovation and Technology and the Green Schools Pilot Initiative target Ontario firms to provide green solutions to government departments and schools, respectively. In addition, the government manages a common purpose procurement program. Second, the government directly supports market demand by offering subsidies and tax rebates for innovative energy products: solar energy systems; vehicles powered by alternative fuels; and wind, micro hydroelectric, and geothermal energy (Government of Ontario, 2010a).

Recall Table 2.4, which suggests that public procurement programs can be evaluated by difference-in-difference estimation. If a public procurement program, by providing a source of demand for innovative products, affects only a sub-group of firms, difference-in-difference estimation can obtain robust estimates of program impact. Apart from this approach, as with policy-making, assessing the state of demand requires a benchmarking exercise.

The State of Firm Innovation in Ontario

Recall Table 3.3, which provides suggested indicators of the state of firm innovation. Many of these indicators have been collected for Ontario:

- *Rate of new venture creation* – Since 2007, the number of firms in Ontario has grown slightly, with virtually all this increase accounted for by firms classified as management in the North American Industry Classification System. There has been a net decline in other leading Ontario industries (e.g., manufacturing; finance; real estate and insurance; and professional, scientific, and technical services). The decline in manufacturing is concentrated in firms with more than 20 employees (Government of Ontario, 2010a).
- *Leading R&D firms* – In 2008, the top 100 R&D performing firms in Ontario performed only half of total industrial R&D. When Ontario is compared to other leading jurisdictions, this percentage is significantly lower and reinforced by the inclusion of only six Ontario companies in the top global 1,000 in 2008: Nortel Networks, BlackBerry, Onex Corporation, OpenText, Biovail Corporation, and Aastra Technologies Limited (European Commission, 2011). This may indicate a weakness in the ability of the Ontario economy to grow, mature, and sustain large, globally competitive "anchor" firms (Miller & Côté, 2012).

- *New or improved products* – Available data for Ontario manufacturing suggest that one-third of firms did not engage in product innovation between 2003 and 2005 since they did not bring a new or improved product to market (Government of Ontario, 2010a). Only 42 per cent of Ontario manufacturing firms brought more than two products to market in the same period. Unsurprisingly, these firms are concentrated in the ICT and pharmaceuticals sectors (Government of Ontario, 2010a).
- *Multifactor productivity (MFP)* – In the most recent estimates (Sharpe & Thomson, 2010), Ontario's MFP level was nine per cent higher than the Canadian average, trailing only Newfoundland and Labrador. MFP contributed 53.6 per cent to labour productivity growth in Ontario, trailing only Newfoundland and Labrador and Nova Scotia.[11] Ontario is the only province to have sustained above average productivity during the 1997–2007 period.
- *GDP* – In 2010, the Ontario private sector produced 81 per cent of GDP, down from 85 per cent in 2002 (Statistics Canada, 2013a). Over the 2002–2010 period, Ontario GDP grew by approximately 4.3 per cent per year. Much of this growth was concentrated in finance/insurance/real estate (from $98 billion to $142 billion), health and social assistance (from $27 billion to $45 billion), and construction (from $23 billion to $41 billion). Manufacturing had the largest decline, from $100 billion to $76 billion (from 21.7 to 12.4 per cent of GDP) (Statistics Canada, 2013a).

Developing an Ontario Innovation Scorecard

As the preceding sections have demonstrated, developing an Ontario innovation scorecard that fully reflects the Panel's firm-centric innovation ecosystem framework is not currently feasible because of insufficient data. First, rigorous estimates of the impact of the suite of innovation support programs (six classes) have not been obtained according to the suggested measurement approaches identified in Chapter 2. Second, with the exception of knowledge generation, much of the data for indicators have not yet been collected. In fact, viable and agreed-upon indicators for policy-making and demand have not even been developed.

11 Since these MFP values were taken at a point in time, they partially reflect factors unrelated to innovation. In the case of Newfoundland and Labrador and Nova Scotia, the effect of high energy prices comprises much of this value.

Table 4.2 provides an overview of indicators that have been collected and those that require collection, and recaps the suggested impact measurement methodologies by innovation support program type. Figure 4.1 superimposes the indicator tables from Chapter 3 onto the schematic of the Ontario innovation ecosystem. The Panel believes:

- program impact measurement would ideally be built directly into innovation support programs;
- more data on indicators of the five aggregate behaviours require collecting, including:
  - repeated sample-based statistical measures (cross-sectional data) to provide evidence on trends; and
  - repeated measures of panel data (longitudinal data) to potentially demonstrate causal links between investments and impacts; and
- benchmarking exercises of policy-making and demand require undertaking.

Given these data limitations, it is not possible to fully identify areas of strength in innovation and innovation support in Ontario. Examining past attempts to measure the impact of innovation investments in Ontario, however, allows partial identification of areas of strength. In this sense, scorecards reside on a continuum, with the Panel's firm-centric innovation ecosystem approach as the best practice and previous scorecards as the best accomplished to date.

The first major attempt to measure the impact of innovation in Ontario was initiated by the now defunct Ontario Science and Innovation Council (Government of Ontario, 2002). The *Ontario Innovation 2002 Index* benchmarked 30 indicators against jurisdictions of similar size and economic structure. The main finding was relative Ontario strength in university research and relative weakness in commercialization (Government of Ontario, 2002).

In 2010, MRI commissioned Program on Globalization and Regional Innovation Systems researchers to develop the *Ontario Innovation Economy Scorecard 2010* (Government of Ontario, 2010a). This report provided a simple logic model that linked investment to impact, and 23 indicators grouped into four categories: innovation investment, innovation capacity, innovation performance, and innovation impact (see Figure 4.2). A 2010 benchmarking exercise revealed, much like the 2002 report, that Ontario provided strong public support for innovation and performed well in higher education research, but was weak in private investment and commercialization. The report concluded that the impact of innovation investments on economic performance was "satisfactory" (Government of Ontario, 2010a).

Since 2010, MRI has commissioned four additional exercises to measure the impact of innovation investments:

- *Innovation Dashboard* (KPMG, 2010a) – A benchmarking exercise to measure the short-term outcomes of public and private innovation activities. The report provided 22 indicators, grouped into four categories: investment, knowledge creation, knowledge transfer and business development, and economic performance.
- *Program Evaluation and Measurement* (KPMG, 2010b) – A program evaluation exercise intended to assess the performance of specific MRI programs in terms of stated objectives and innovation fostering.
- *Employment Research and Analysis* (PwC, 2010) – A forecasting model projecting the potential impacts of innovation on GDP growth, job creation, labour income, and tax revenue over 1-, 5-, 10-, and 20-year periods.
- *Program Evaluation and Measurement* (KPMG, 2011) – An analysis of three online surveys and interviews with key stakeholders that received MRI funding.

These innovation measurement frameworks provide important indicators (Government of Ontario, 2002, 2010), benchmarks (Government of Ontario, 2002, 2010; KPMG, 2010a; PwC, 2010), and qualitative data (KPMG, 2010b; 2011). As mentioned, however, none fully reflects the Panel's firm-centric innovation ecosystem framework.

4.3 EVALUATING THE STATE OF THE ONTARIO INNOVATION ECOSYSTEM — QUALITATIVE ANALYSIS

By focusing on aggregate behaviours, the Panel's firm-centric innovation ecosystem framework avoids the numerous interactions and feedback loops that render innovation a complicated process at the micro level. Like any model, it is an abstraction from reality that serves a useful purpose by organizing impact measurements (Chapter 2), and quantitatively assessing the state of an innovation ecosystem through the scorecard approach discussed above.

Largely quantitative approaches often miss important contextual features of an innovation ecosystem, and hide details of the interactions and feedbacks at the micro level. Quantitative analysis alone does not capture shifts in the mix, or expansions in the scope, of innovation investments and innovation policy. Reinhilde Veugelers, chairperson of the international evaluation team of the Finnish innovation system, argues: "Innovation policy remains an art rather than a science … One should more often have an overall systemic view of the incentives and actions of individuals and organizations currently targeted by a bewildering array of instruments … measures [of] how they work in tandem is largely unknown" (Finnish Government, 2009).

Table 4.2

Components of an Ontario Innovation Scorecard

Aggregate Behaviour	Previously Collected Indicators	Additional Required Indicators	Program Type	Suggested Measurement Methodology
Knowledge Generation	Higher education expenditure on R&D (HERD) S&T outputs (publications and patents) Highly cited scientists Public-sector R&D personnel University graduates College graduates Business enterprise expenditure on R&D (BERD) R&D outputs (patents and publications) Industry R&D personnel		**Direct academic support**	Regression discontinuity design
			Public and not-for-profit research organizations	Regression discontinuity design

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Table 4.2

Components of an Ontario Innovation Scorecard

Aggregate Behaviour	Previously Collected Indicators	Additional Required Indicators	Program Type	Suggested Measurement Methodology
Innovation Facilitation	BERD (by funder) Innovation program direct business funding Venture capital and angel funds Leveraged funds Tax credits Contracts and intellectual property agreements; spinoffs	Application decision time Innovation intermediary in-kind assistance Mentoring/advice Access to global networks Level of collaboration (i.e., public-private) Foreign direct investment (FDI)	**Innovation intermediaries**	Random field experiments Matching estimation Client-based surveys
			Direct business support	Random field experiments Matching estimation Client-based surveys
			Indirect business support	Random field experiments Matching estimation Client-based surveys
Policy-making	Requires a benchmarking exercise			
Demand	Requires a benchmarking exercise		**Public procurement**	Difference-in-difference estimation
Firm Innovation	Rate of new venture creation Leading R&D firms New or improved products Aggregate productivity GDP		Crépon, Duguet, and Mairesse (CDM) model	

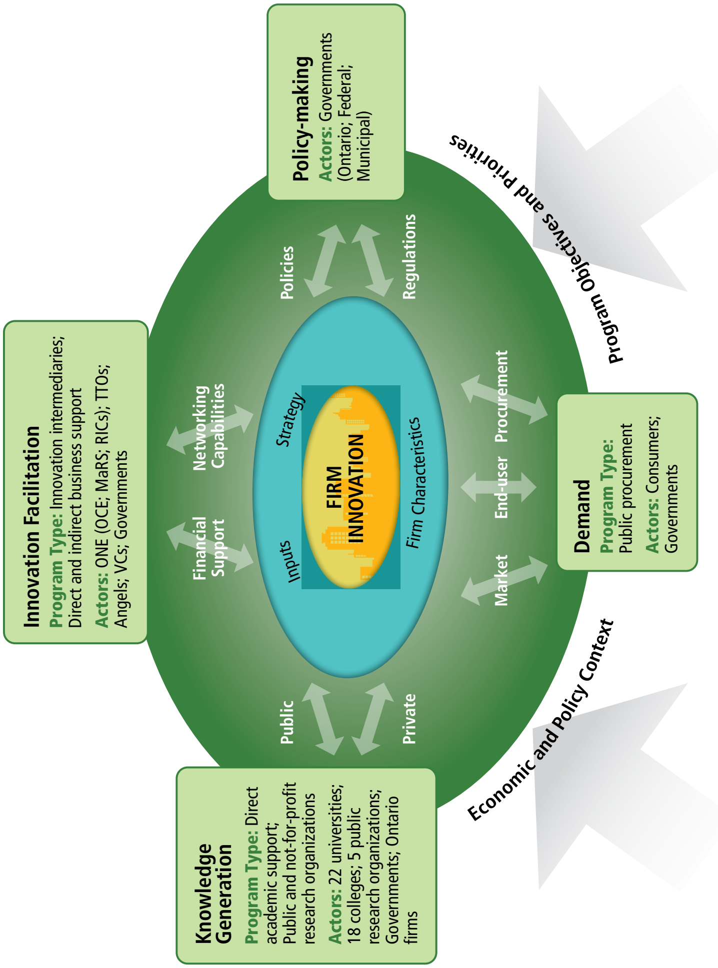

Figure 4.1
The Ontario Innovation Ecosystem

Measurement Framework		Indicators
Innovation Impact	Economic Performance	productivity
		employment growth
		economic well-being
Innovation Performance	Research and Education	skilled graduates
		research publications
	Technology Development and Transfer	patents
		university technology transfer
	Commercialization	product innovation
		high-wage employment
		firm entrants and exits
Innovation Capacity	Higher Education and Public Research	highly cited scientists
		stock of public sector R&D personnel
		level of collaboration
	Linkages and Support	stock of industry R&D personnel
	Companies	employment by industry clusters
		creative economy
		leading R&D companies
Innovation Investment	Public Investment	gross expenditures on R&D
		federal and provincial research support
		research infrastructure
	Private Investment	business R&D
		venture capital investments
		investments in ICT, machinery and other equipment

Reproduced and adapted with permission from the Ontario Ministry of Research and Innovation (2010).

Figure 4.2

Ontario Innovation Economy Scorecard Measurement Framework

The Panel concluded that qualitative methods should be used to complement quantitative approaches to innovation ecosystem assessment. This is in keeping with the OECD Innovation Strategy (OECD, 2010d) and measurement practices (OECD, 2010a) which promote a mix of quantitative and qualitative analysis, to understand innovative behaviour, its determinants, and its impacts at the level of the individual, firm, and organization. Three qualitative methods are particularly useful: case studies, surveys, and independent innovation ecosystem evaluations. Innovation case studies and surveys can be conducted of specific innovation actors (e.g., innovation intermediaries); economic sectors; or entire ecosystems. For instance, the OECD combines these qualitative approaches to examine high-growth firms; technology-intensive industries (e.g., biotechnology and ICT); and country-by-country ecosystems. Boxes 4.1 and 4.2 provide case studies of the Waterloo regional ecosystem and the Ontario automotive sector ecosystem, respectively. Highlighting key features of the ecosystems, the case studies demonstrate how the Panel's framework can be applied.

Independent innovation investment and ecosystem evaluations consider the impact of various government investments in the context of innovation objectives and the innovation ecosystem. Globally, national and sub-national governments and key innovation institutions have commissioned independent evaluations, often conducted by blue ribbon panels of foreign innovation ecosystem experts. According to OECD (2013), the Nordic evaluation culture is often seen as a model for applying qualitative methods to innovation ecosystem evaluation.

Finland

Independent innovation investment and ecosystem assessments are widely used to guide innovation investments and policy in Finland. They are commissioned to assess the effectiveness of various organizations and programs (e.g., government departments; universities; and Tekes and the Academy of Finland, and their programs). Tekes — Finland's main public research funding agency — which monitors and measures the results of all funded projects — often commissions external researchers to assess its project portfolio and funding program mix (Dalziel & Parjanen, 2011). In addition, the Research and Innovation Council publishes an assessment of the Finnish ecosystem every four years, which sets out the guidelines for future innovation policy (Finnish Government, 2010).

In 2008, the Ministry of Education and the Ministry of Employment and the Economy commissioned an international evaluation of the Finnish national innovation ecosystem (Finnish Government, 2009). Intended to provide an independent "outsiders'" view of the entire system — not just of the individual actors or investments — the evaluation was based on the principles of the National Innovation Strategy (Finnish Government, 2006). The evaluation had four main objectives:

- form an outside view of major drivers of change in the system and evaluate how well they are addressed in innovation policy;
- identify ways of addressing current and future challenges;
- indicate where institutional and policy adjustments and reforms are needed; and
- draw conclusions and make recommendations for policy governance and steering (Finnish Government, 2009).

This evaluation identified two critical bottlenecks in the Finnish innovation ecosystem — limited growth in entrepreneurship and access to global markets — and noted that the ecosystem was overly complicated, with a fragmented structure. As a result, it recommended a significant reform of the ecosystem to develop an international dimension, and to increase support and simplify the structure for start-ups and small businesses.

Box 4.1
The Waterloo Innovation Ecosystem

Over the last 50 years, the Waterloo region has become one of the most dynamic innovation clusters in North America. Some of this success can certainly be traced to the establishment of the University of Waterloo (UW) and its exemplary co-operative education program. Waterloo's emergence as a leading high-technology cluster, however, did not occur until at least 30 years after the founding of UW: the time needed, according to the Panel's framework, to develop a healthy innovation ecosystem. Applying the Panel's firm-centric innovation ecosystem framework offers insight into the interactions of innovation actors and the importance of particular innovation investments. This is accomplished by analyzing the five aggregate behaviours that emerge from this network of micro-interactions.

Knowledge Generation

UW was founded in 1957 in response to a growing demand from industry for well-trained graduates in science, math, and engineering. Recognizing the need for more technical education, UW developed a co-operative education program that tied undergraduate education to practical industry experience. This co-op program is widely regarded as one of the best in North America, providing students and firms with the means to create new ideas, share knowledge, and develop entrepreneurial skills (Bramwell & Wolfe, 2008). During these formative years, UW developed a world-leading computer science program, partially owing to the creation of WATFOR and WATFIV compliers,

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which were commercialized by WATCOM (founded in 1981) and offered computing access to all undergraduates (CCA, 2009). Taken together, these developments enabled UW to attract top-flight faculty and grow into a leading-edge university.

Today, UW continues to function as a critical catalyst for regional innovation by helping create spinoff companies and developing a robust pool of HQP. Other knowledge-generating institutions also play important roles in developing HQP, including the University of Guelph, Wilfred Laurier University, Conestoga College, and 150 local research institutes (Bramwell *et al.*, 2012).

Innovation Facilitation

Initially, UW informally assisted academic researchers looking to commercialize ideas and create start-ups by renting them lab space and specialized equipment. In the early 1980s, the Canadian Industrial Innovation Centre (CIIC) was created to more formally assist start-up firms by providing training, office space, and guidance on how to obtain funding (CCA, 2009). With the decline of the traditional manufacturing base (e.g., rubber, chemicals, and furniture) in Waterloo during the 1990s, the local government helped spur the continued growth of high-technology firms by providing low-cost land and forming an industry association, Communitech, in 1997. This was followed by the creation of the Accelerator Centre in 2006. Supported by UW, the federal and provincial governments, and local business, it delivers access to business mentors, an advisory board of local entrepreneurs; and training programs to start-up companies with pre-existing funding and viable business plans. Waterloo's active angel and venture capital community contributed $300 million to local firms in 2009 (Bramwell *et al.*, 2012).

Policy-making

The robust links between UW and cluster firms have been enhanced not only by the co-op program, but also by the university's intellectual property (IP) policy, which grants full IP ownership to the creator and encourages faculty and students to commercialize their ideas (Bramwell & Wolfe, 2008). This is demonstrated by the development of several high-profile software and digital media companies (e.g., OpenText, DALSA, BPI), which were based on patented technology originally developed at UW. In addition, as discussed above, the Government of Ontario was instrumental in the development of a wide class of innovation intermediaries (CIIC, Communitech, Accelerator Centre, David Johnston Research and Technology Park, etc.); and in the implementation of several sector-based strategies like the Biotechnology Cluster Innovation Program. Despite these investments, research has shown that the rate of spinoff formation has slowed considerably over the last decade (Kenney & Patton, 2009).

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Demand

A key driver of the Waterloo cluster has been the relationships between Waterloo firms and their global customers, sources of supply, and strategic partnerships. Most firms in the cluster have an explicit global focus because often "their largest customer contributes only a small percentage of total revenue" (Bramwell *et al.*, 2012). This global competition forces Waterloo firms to compete on the novelty and quality of their products, rather than on cost. In a few cases, firms have developed strategic relationships with their customers through various funding and IP relationships.

Firm Innovation

Beginning with WATCOM, the first generation of spinoff firms emerged from UW in the early 1980s, including world leaders like BlackBerry, OpenText, and DALSA. These large "anchor" firms provided small and medium-sized enterprises (SMEs) with a source of demand through specialized supply contracts, and connected them with a local talent pool of well-trained individuals. Waterloo is often differentiated from other leading North American clusters by the prevalence of SMEs; and from other leading Canadian clusters by the rate of patents granted — 631 patents per million people per year, or three times the Canadian average (Bramwell *et al.*, 2012). In 2009, 711 technology firms employed 30,000 individuals, conducted $350 million of R&D, and generated $18 billion in combined revenue (Bramwell *et al.*, 2012). Many of these firms emphasize "solutions-focused, incremental innovations rather than research-intensive, first generation innovations" in their business models (Bramwell *et al.*, 2012).

Waterloo's success as an innovation cluster can be traced to the development of UW as an "entrepreneurial university" and a set of investments that helped create a healthy innovation ecosystem to spur firm innovation. It would be difficult, if not impossible, to replicate Waterloo's development path because its innovation ecosystem has evolved over time (CCA, 2009). Examining the five aggregate behaviours of the Panel's framework, however, sheds some light on which innovation investments have had the greatest catalytic effects on the Waterloo regional innovation ecosystem.

Box 4.2

The Ontario Automotive Innovation Ecosystem

The automotive sector is critical to Ontario. In 2009, it contributed approximately $10 billion to GDP, employed 82,000 individuals in relatively high-paying jobs, and accounted for 37 per cent of exports (Statistics Canada, 2013a, 2013b; Government

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of Ontario, 2013a). This sector encompasses the entire Ontario supply chain from materials production to parts manufacturing to vehicle assembly. Given the diversity of economic production in a single sector, it is important to understand how particular innovation investments support the wide range of innovation activities. This is accomplished by analyzing the five aggregate behaviours that emerge from this network of micro-interactions.

Knowledge Generation

In addition to the basic and applied research and HQP training undertaken in Ontario universities and colleges, several public research organizations enhance the state of automotive sector-relevant knowledge. The Initiative for Automotive Manufacturing Innovation, formed through collaboration between McMaster University, the University of Waterloo, the Ontario government (through the Ontario Research Fund), and 35 industrial partners, is a research cluster intended to develop new technologies for producing lightweight, lower-cost automobiles (IAMI, 2013). The Magna-NRC Composite Centre of Excellence is focused on the development of "green" automotive parts. In addition, other important public research organizations help develop new ideas, including the Centre for Advanced Materials and Manufacturing, the Waterloo Centre for Automotive Research, and the McMaster Manufacturing Research Institute.

Innovation Facilitation

The Automotive Centre of Excellence (ACE) is a $100-million multi-purpose centre developed in partnership with the University of Ontario Institute of Technology, General Motors of Canada, the Government of Ontario, the Government of Canada, and the Partners for the Advancement of Collaborative Engineering Education (ACE, 2013a). It is the first testing and research centre of its kind in Canada, bringing together academia (both faculty and students) and industry in an environment suitable for collaboration, interaction, and commercialization of academic research (ACE, 2013b). Its 16,300-square-metre facility "is commercially available to customers who are seeking to bring their ideas into a proof of concept and ready for market. In addition to conventional automotive applications, ACE is suitable for testing alternative fuel, hybrid and electric vehicles" (ACE, 2013b).

Other important innovation intermediaries include AUTO21 and the Centre of Excellence for Materials and Manufacturing, which facilitate collaboration between academic researchers and firms. The federal government established the $250-million Automotive Innovation Fund to support strategic, large-scale R&D projects to build innovative, greener, and more fuel-efficient vehicles (Industry Canada, 2013). It is geared towards supporting Canada's environmental agenda for developing fuel-efficient cars and reducing greenhouse gases.

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Policy-making

Innovation in the automotive sector is often in response to government regulations on fuel emissions and vehicle safety standards. For instance, with the goal of having five per cent of Ontario cars electrically powered by 2020, the Government of Ontario has provided support for a joint GM-Magna E-Car Systems project to develop the next generation of clean vehicle technologies, and built critical infrastructure like charging stations (Government of Ontario, 2010b).

Demand

As part of the North American Free Trade Agreement, Ontario-based auto manufacturers have access to the enormous U.S. market. With the appreciation of the Canadian dollar vis-à-vis the U.S. dollar and declining global demand, however, the Ontario automotive sector is under increasing pressure to produce high-quality, low-cost automobiles to capture a share of demand. In this sense, demand is perhaps the critical driver of productivity increases (i.e., labour hours per vehicle) (CCA, 2009). The Government of Ontario itself also provides a source of demand. For instance, to support electric car demand, it provides a subsidy of between $5,000 and $8,500, and offers drivers "green license plates" that allow them to use the province's network of faster High Occupancy Vehicle lanes. In addition, the government has set a public procurement target of 20 per cent for electric public service passenger vehicles by 2020.

Firm Innovation

Ontario is home to 11 assembly plants operated by five of the world's top automakers: General Motors, Ford, Chrysler, Honda, and Toyota. The first three — the so-called "big three" — represent more than two-thirds of vehicle production; however, much of their R&D and innovation are sourced to the United States (CCA, 2009). Ontario is also home to over 300 auto parts manufacturers including Ontario-based companies ABC Group, Woodbridge Group, Linamar, and Magna International (North America's largest manufacturer). These firms are at the leading edge of automotive innovation. Taken together, average productivity in the Ontario automotive sector exceeds the U.S. level (CAW, 2008).

The diversity of the Ontario automotive sector requires a varied set of innovation investments to support a wide range of activities. Analyzing the automotive innovation ecosystem according to the five aggregate behaviours of the Panel's framework highlights the bottlenecks that hinder innovation, and the leverage points that drive innovation. Understanding an innovation ecosystem at the sectoral level can also be an instructive microcosm of higher-level ecosystems at the regional or national level.

Sweden

In contrast to the trend towards more quantitative analysis across OECD countries, Swedish policy-makers rely heavily on qualitative methods to conduct ecosystem assessments. An OECD report (2013) on the Swedish innovation ecosystem provides an excellent example of the role of qualitative analysis in assessing the state of an ecosystem. Drawing on interviews with major innovation stakeholders, the report:

- provides an independent and comparative assessment of the overall performance of Sweden's national innovation system (innovation ecosystem);
- recommends where improvements in the ecosystem can be made; and
- highlights how government policies can contribute to such improvements, drawing on the experience of other OECD countries and evidence on innovation processes, systems, and policies.

(OECD, 2013)

In general, Sweden has a strong record in using independent ecosystem assessments to guide innovation investment and policy (OECD, 2013). For instance, VINNOVA — Sweden's leading innovation-funding agency — has built evaluation directly into its funding programs, and often conducts these evaluations through blue ribbon panels of foreign innovation ecosystem experts. In 2008, VINNOVA commissioned an evaluation of funding programs over the previous 20 years. The resulting incremental learning, at both the program and institutional levels, was an important outcome of these evaluations and essential to more effective innovation investment and policy (OECD, 2013).

Denmark

Since 2010, the Danish Agency for Science, Technology and Innovation (DASTI) commissioned nine independent evaluations of Danish innovation investments and the innovation ecosystem (reviewed in Christensen, 2012), which built on the work of the European Research Area (Technopolis Group, 2010). For example, DASTI (2012) explored the critical elements of the Danish innovation ecosystem, and assessed the economic impacts of various innovation intermediaries (e.g., Danish Innovation Incubator Scheme, The Technology Transfer Offices, Knowledge Pilot Scheme, etc.). In addition, this evaluation considered the economic impact of all Danish innovation investments and policy using a macro-economic model of Denmark.

Netherlands

Innovation ecosystem assessment and monitoring are also well established in the Netherlands, with external parties often conducting evaluations (OECD, 2005). The Dutch governance system involves three main advisory bodies in evaluation: Advisory Council for Science and Technology Policy, Netherlands Bureau for Economic Policy Analysis (CPB), and the Court of Audit. In 2011, CPB (2011) published an extensive review of best practices in impact assessment and the role of government in correcting market failures in innovation. It found that innovation investments and policy are most effective when objectives are well articulated; and empirical results from past evaluations may no longer be relevant owing to shifts in innovation investments, policy, and other contextual features of the innovation ecosystem. As such, evaluation should be built into program design.

Lessons for Ontario

This review of international practices has highlighted how governments can use independent innovation investment and ecosystem evaluations to increase the effectiveness of the ecosystem by pinpointing bottlenecks and leverage points for innovation investments and policy to exploit. These evaluations enable governments to monitor the state of the innovation ecosystem. Continually commissioning and updating evaluations of the impact of innovation investments and the state of the innovation ecosystem are standard practice in many leading innovation countries. It follows that the Government of Ontario could also constantly update measurements, monitor the innovation ecosystem, and conduct periodic independent ecosystem evaluations.

4.4 CONCLUSION

This chapter has highlighted how program impact measurements (Chapter 2) and indicators of aggregate behaviours (Chapter 3) can be combined to develop a scorecard — a quantitative assessment of the state of an innovation ecosystem. Since quantitative approaches often miss important contextual features of an innovation ecosystem, quantitative analysis must be complemented with qualitative approaches like case studies, surveys, and independent innovation ecosystem evaluations.

Applying this approach in Ontario requires several commitments. First, to rigorously and reliably estimate program impact, according to the methodologies suggested in Chapter 2, program evaluation would ideally be built directly into innovation programs. Second, more indicators of the five aggregate behaviours require collection, based on data from repeated cross-sectional observations and longitudinal data. This includes conducting benchmarking exercises of policy-making and demand. Together, these two tasks can enable construction of an Ontario innovation scorecard that fully reflects the Panel's firm-centric innovation ecosystem framework. Third, the state of the Ontario innovation ecosystem could be constantly monitored by updating program impact measurements and commissioning independent innovation and ecosystem evaluations.

5

Conclusions

- Responding to the Charge
- Responding to the Sub-questions
- Final Reflections

5 Conclusions

This chapter synthesizes the main findings that emerged from the Panel's deliberations, provides answers to the main question and sub-questions that comprise the charge, and offers some final reflections.

> "If you always do what you always did, you will always get what you always got."
> Albert Einstein

5.1 RESPONDING TO THE CHARGE

Main Question

How can the actual and potential outcomes and impacts of Ontario government spending on innovation and scientific activities be measured, including but not limited to the effects on GDP in Ontario, generation and transfer of knowledge; creation of new ventures; and access to seed, development and growth capital?

Measuring the impacts of the Government of Ontario's investments in innovation requires four steps. First, cataloguing innovation investment programs highlights what constitutes an investment. At the program level, the Panel identified six classes of Ontario innovation support programs: direct academic support, public and not-for-profit research organizations, innovation intermediaries, direct business support, indirect business support, and public procurement.

Second, identifying program objectives delivers guidance on what impacts to expect — that is, what can and should be measured for a program. The Panel identified the likelihood of seven types of impact for each of the six classes of Ontario innovation support.

Third, collecting data, either from administrative records and surveys or through program design, determines the most appropriate measurement technique. The robustness and reliability of an impact measurement depend on the type and quality of data collected. In fact, the usefulness of the sophisticated best practice econometric approaches to program evaluation is sometimes limited by a lack of data.

Fourth, using leading-edge econometric approaches to program evaluation (random field experiments, regression discontinuity design, matching estimation, and difference-in-difference estimation) can provide robust and reliable measurements of program impact. These approaches require skilled and experienced analysts and a significant time commitment to interpret results. The Panel identified how and when to best use these measurement tools for Ontario's innovation support programs.

Program impact measurements alone, however, cannot capture the nature of innovation. Innovation is not a process isolated at the program level, with a linear relationship from investment to impact. Assessing the full impact of innovation investments requires capturing their contributions to the functioning of the entire innovation system. The Panel's firm-centric innovation ecosystem framework conceptualizes innovation as the result of an intricate set of activities and linkages between innovation actors. The state of five behaviours that emerge from this network of micro-interactions — knowledge generation, innovation facilitation, policy-making, demand, and firm innovation — governs the effectiveness of the innovation ecosystem in fostering and sustaining firm innovation, and ultimately generating impact. It follows that the state of the entire innovation ecosystem can be assessed by examining indicators of the five aggregate behaviours.

5.2 RESPONDING TO THE SUB-QUESTIONS

Sub-question 1

Based on the rigorous review of current studies and the identification of the most appropriate evaluation methods, is it feasible to build a model to quantify the returns on innovation investment of the government of Ontario in terms of socio-economic effects such as output, employment, tax, creation of new ventures, development of entrepreneurship and social impacts?

Program impact measurement can provide robust and reliable estimates of the returns to innovation investments. There is, however, an important and fundamental trade-off between the timeframe (and data requirements) in which impact measurement can be conducted and the robustness of these estimates. If the goal of measurement is to produce estimates of *short-term* impact, the best source of data is a properly designed client-based survey that minimizes the subjectivity of responses. If the goal of measurement is to firmly establish rigorous, reliable, and *long-term* causal estimates of program impact, state-of-the-art approaches, like random field experiments and regression discontinuity design, require a specific program design, a substantial quantity of data, and a significant amount of time. Ultimately, the feasibility of a measurement methodology depends not only on the goals of measurement, but also on the objectives and structure of an innovation program, which determine the expected socio-economic impacts.

Program impact measurements and indicators of aggregate behaviours can be combined to quantitatively assess the state of the innovation ecosystem. This involves developing a scorecard that organizes rigorous estimates of the returns to innovation investments at the program level by the ecosystem behaviour the program supports. Measurements and indicators can be compared over time or across jurisdictions. This approach is not currently feasible because of insufficient data for Ontario.

Applying the approach suggested in this report requires several commitments. First, to rigorously and reliably estimate program impact, according to the methodologies suggested in Chapter 2, program evaluation would ideally be built directly into innovation programs. Second, more indicators of the five aggregate behaviours require collection, based on data from repeated cross-sectional observations and longitudinal data. This includes conducting benchmarking exercises of policy-making and demand. Together, these two tasks can enable construction of an Ontario innovation scorecard that fully reflects the Panel's firm-centric innovation ecosystem framework. Third, the state of the Ontario innovation ecosystem could be constantly monitored by updating program impact measurements and commissioning independent innovation investment and ecosystem evaluations.

Sub-question 2 and 2.1

How can the returns (socio-economic impacts) on innovation investments by the government of Ontario be defined and evaluated?

What methods for assessing and quantifying the actual and potential returns on innovation investments are used by other jurisdictions?

The difficult, if not daunting, task of measuring the impacts of innovation investments has been on the radar of jurisdictions across the globe for several decades. As such, jurisdictions have developed wide-ranging and diverse methodologies to measure the impacts of innovation investments at the national, regional, and industry levels.

The scorecard approach — which categorizes the inputs, outputs, and impacts of innovation investments — is widely used. Annually, the OECD publishes the Science, Technology and Industry Scoreboard, providing data on OECD countries; and the European Commission publishes both a Global and European Innovation Scoreboard. In the United States, scorecards have been published by the governments of Massachusetts, Maine, Michigan, and Oregon. In Canada, Industry Canada's Science, Technology and Innovation Council (STIC) has produced two State of the Nation reports, and the Council of Canadian Academies has published two reports on the state of science and technology (S&T) and one on the state of R&D in Canada. Scorecards have also been produced in Alberta and Quebec. Based on simple logical frameworks populated with a wide range of indicators, indicator-based assessment frameworks are used to assess impacts of investments in innovation by the Australian Department of Industry, Innovation, Science, Research and Tertiary Education; Tekes in Finland; and the Canadian Academy of Health Sciences.

The Crépon, Duguet, and Mairesse model is a leading general econometric approach to measuring the impact of innovation investments on firm production. It has been employed by 18 OECD countries, including Canada, in the Innovation Microdata Project. The finance departments of many jurisdictions use growth accounting to measure the impact of innovation on economic performance.

Econometric approaches to program evaluation are the leading-edge methodologies. These methods consist of estimating the impact of innovation investments (independent variable) on firm performance (dependent variable). This requires comparing the average performance of the participating firms (e.g., revenue, new products, employment, etc.) to the average performance of the same firms if they had not participated in the program by identifying a control group. Several techniques have been developed to find the best control group and ultimately provide a causal estimate of impact. Four best practice econometric program evaluation techniques were identified: difference-in-difference estimation, matching estimation, regression discontinuity design, and random field experiments. The first two techniques identify a sub-group of non-participating firms that are similar enough to the participating firms for the comparison to be valid, while the last two techniques introduce randomization in the assignment to the program. For all four methods, the impact of the program is the difference in average performance between the two groups. The main difference between the techniques is the way the control group is constructed. These approaches have been used to measure the impact of various programs; however, the Panel is not aware of any jurisdictions that have built econometric program impact measurement into program delivery.

Many leading innovation countries (Finland, Sweden, Denmark, and the Netherlands) frequently update program evaluations and commission blue ribbon panels of foreign experts to conduct innovation ecosystem evaluations.

Sub-question 2.2

How can these methods be applied to Ontario?

As demonstrated in Chapter 4, program impact measurement (Chapter 2) and innovation ecosystem assessment (Chapter 3) can be combined to develop an Ontario scorecard of the state of the five aggregate behaviours of the firm-centric innovation ecosystem. First, the Panel has identified six classes of Ontario innovation support programs, the likelihood of seven types of impact for each class, and how to apply leading-edge economic approaches to program evaluation. To conduct rigorous program impact measurement, program evaluation would ideally be built directly into innovation program design in Ontario. Second, the Ontario innovation ecosystem can be assessed by examining indicators of the five aggregate behaviours of the firm-centric innovation ecosystem. This requires collecting more indicators, both cross-sectional and time series, and conducting benchmarking exercises of policy-making and demand. Overall, the state of the Ontario innovation ecosystem could be constantly monitored by updating program impact measurements and commissioning independent innovation investment and ecosystem evaluations.

Sub-question 3

Identify Ontario's area of strength of innovation and innovation support.

There are insufficient data to fully identify areas of strength in innovation and innovation support in Ontario in accordance with the Panel's firm-centric innovation ecosystem framework. First, rigorous estimates of the impact of the suite of innovation support programs (six classes) have not been obtained according to the suggested measurement approaches identified in Chapter 2. Second, with the exception of knowledge generation, much of the data for indicators of the aggregate behaviours of the innovation ecosystem have not yet been collected. In fact, viable and agreed-upon indicators for policy-making and demand have not even been developed. Considering past attempts to measure the impact of innovation investments in Ontario, however, allows partial identification of areas of strength. In this sense, scorecards reside on a continuum, with the Panel's firm-centric innovation ecosystem approach as the best practice and previous scorecards as the best accomplished to date.

The *Ontario Innovation 2002 Index*, which benchmarked 30 indicators against jurisdictions of similar size and economic structure, found relative Ontario strength in university research and relative weakness in commercialization. The *Ontario Innovation Economy Scorecard 2010* considered 23 indicators grouped into four categories: innovation investment, innovation capacity, innovation performance, and impact (see Figure 4.2). This benchmarking exercise revealed, much like the 2002 report, that Ontario provided strong public support for innovation and performed well in higher education research, but was weak in private investment and commercialization.

5.3 FINAL REFLECTIONS

Although a formidable undertaking requiring significant resources, measuring the impact of innovation investments ensures that the most effective innovation programs are supported with secure, stable, and sufficient funding in the face of competing demands and austerity measures. Similarly, while assessing the state of the innovation ecosystem requires significant commitment, it is critical for pinpointing bottlenecks in the system that hinder innovation, and identifying leverage points to drive innovation.

In general, innovation investment and policy are likely to be most effective as a long-term strategy if based on the most robust estimates of program impact and the most up-to-date and comprehensive picture of the entire system. With shifting economic and social circumstances, it is unlikely that governments can continue doing what they always have done in innovation investment and policy. Measurement and assessment enable the most effective innovation investments and efficient innovation policies. These investments and policies are, and will continue to be, critical for Ontario's economic and social progress.

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Appendix A

- This appendix offers an overview of Ontario innovation programs to provide a more comprehensive picture of the funding landscape.

Program	Eligibilty	Program Details and Funding
Direct academic support		
Ontario Research Fund (ORF)	Researchers from publicly funded research institutions	Created in 2004 to "support scientific excellence by supporting research that can be developed into innovative goods and services that will boost Ontario's economy", the ORF is funded and delivered by MRI. There are two main programs: • ORF-Research Excellence (ORF-RE): covers the operational costs, direct and indirect, of research. • ORF-Research Infrastructure (ORF-RI): covers the capital costs of acquiring, developing, modernizing, or leasing research infrastructure up to a maximum of 40 per cent of the total eligible costs. Total program spending between 2004 and the end of the 2010/2011 fiscal year was $569 million ($303 million from 2004/2005 to 2008/2009). Total announced program commitments from 2004/2005 to 2010/2011 were $1.077 billion ($623 million from 2004/2005 through 2008/2009) (Office of the Auditor General of Ontario, 2011). Since 2006, MRI has invested $368.6 million in ORF-RE to support 91 research projects while leveraging $730.8 million from over 450 industry, institutional, and federal partners. Since 2004, MRI has committed over $571 million to ORF-RI to cover the infrastructure costs of 1,165 research projects across the province. ORF-RI has also leveraged nearly $1.4 billion from the federal government and institutional partners (Office of the Auditor General of Ontario, 2011). In 2011, citing "the current fiscal challenges," the Government of Ontario cancelled round six and seven of ORF-RE, as well as the special round for the social sciences, arts, and humanities. The Auditor General of Ontario found that most of the $623 million committed to projects at the time was for basic theoretical research not focused on commercial potential, as stipulated in the mandate of the program (Office of the Auditor General of Ontario, 2011).
Early Researchers Award (ERA)	Full-time faculty of publicly funded research institutions, no more than five years from having started their independent academic research careers	The maximum award to a researcher is $100,000 for a period of five years. By 2010, MRI had awarded $58.7 million to 419 promising recently appointed researchers to help them build their research teams (Government of Ontario, 2013c).

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Program	Eligibilty	Program Details and Funding
Post-doctoral Fellowship (PDF)	PhD graduates intending to do post-doctoral study at an Ontario university	The program provides outstanding scientists with two-year fellowships at Ontario research institutions, with a minimum of $50,000 per year. By 2010, MRI had provided the PDF program with $9.8 million to support 196 post-doctoral fellows in Ontario (Government of Ontario, 2013d).
International Strategic Opportuni-ties Program (ISOP)	- Academics, direct - Support for public R&D activities - Not-for-profit organizations in which Ontario researchers are engaged in strategic international collaborations	The program provides funding for strategic international collaborations between Ontario research institutions and the global research community. Total funding per research collaboration initiative usually does not exceed $150,000 over three years. Since 2005–2006, MRI has funded 20 international research collaborations through ISOP, totalling $2.8 million (Staff calculations).
OMAFRA-University of Guelph Partnership Research	- Academics, direct - Support for public R&D activities	In 2008, the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the University of Guelph renewed their research partnership for a 10-year period (2008-2018). The partnership includes agri-food and rural research programs, laboratory services, and veterinary clinical education programs. The university will receive over $350 million between 2008 and 2013 (Government of Ontario, 2013e).
Public and not-for-profit research organizations		
Ontario Insti-tute for Cancer Research (OICR)	N/A	OICR is an MRI-funded, independent, not-for-profit research institute committed to undertaking research on the causes and treatment of cancer. From 2006–2007 to 2011–2012, MRI provided OICR with $410 million, with another $90 million committed for 2012–2013 (OICR, 2012).
Ontario Brain Institute (OBI)	N/A	Funded by MRI and donations from the private sector, OBI supports large-scale collaborative projects between Ontario brain researchers, clinicians, and institutions, and serves as a bridge between academia and industry. Since 2011–2012, MRI has invested $6.59 million in OBI, with another $7.56 million committed for 2012–2013 (OBI, 2010).

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Program	Eligibilty	Program Details and Funding
Perimeter Institute for Theoretical Physics	N/A	The Perimeter Institute is a basic research centre dedicated to exploring foundational issues in theoretical physics. Since beginning operation in 2001, it has grown to include over 80 resident researchers. It receives funding from the federal government, provincial government, non-profit foundations, individuals, and private-sector corporations. To date, MRI has invested $10 million in the Perimeter Institute.
Agricultural Research Institute of Ontario (ARIO)	N/A	ARIO provides advice to the Minister of Agriculture, Food and Rural Affairs on strategic directions for research activities that contribute to prosperous, competitive, and sustainable agricultural and food sectors and rural communities in Ontario. ARIO owns 14 research stations and 3 agricultural colleges in Ontario. These facilities provide the capacity for research on a wide variety of agri-food issues.
Ontario Forest Research Institute (OFRI)	N/A	Funded by the Ontario Ministry of Natural Resources, OFRI develops new scientific knowledge to support the sustainable management of Ontario's forests. It houses about 50 researchers in a 9,000-square-metre research facility.
Innovation intermediaries		
Ontario Network of Excellence (ONE)		Announced in 2009–2010, ONE is a revitalized, client-focused innovation network, which strives to align all of Ontario's programs and resources for supporting innovation actors.
Ontario Centres of Excellence (OCE)	Early-stage companies	OCE was established by the Government of Ontario to strengthen the research linkages between academia and industry. It co-invests to commercialize innovation originating in the province's colleges, universities, and research hospitals, especially through the Industry Academic Collaboration Program. From 2006–2007 to 2008–2009, MRI provided OCE with $102 million in funding. No other data are publicly available on how much funding OCE receives.

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Program	Eligibilty	Program Details and Funding
MaRS	Early-stage companies	Officially starting operations in September 2005, MaRS, a 700,000-square-foot complex that houses science and technology research labs alongside technology companies and investment capital firms, continues to receive support from MRI. It has delivered many innovation programs on behalf of MRI. In 2006 and 2007, MaRS received $3.8 million from MRI. No other data are publicly available on how much funding MaRS receives.
Business Ecosystem Support Fund (BESF)	N/A	The program supports sophisticated industry-academic partnerships that will accelerate product development in emerging global markets. From 2009 to 2011, MRI provided support to four innovation centres: $13.6 million to GreenCentre Canada to develop the next generation of green industrial products; $9.3 million to Coral CEA to help Ontario companies in the global communications enabled applications market; $26.4 million to Communitech to ensure Ontario maintains a leadership position in the growing market for digital media and mobile computing applications; and $21 million to the Health Technology Exchange to help it partner with innovative companies, research institutions, and health providers (Staff calculations).
Health Technology Exchange (HTX)	Medical technology companies	Established in 2004 with the continuing support of the Government of Ontario, HTX seeks to accelerate innovation, commercialization, and the growth of Ontario's medical and assistive technologies sector.
Centre for Research and Innovation in the Bio-economy (CRIBE)	Companies in forest product industries	CRIBE assists the commercialization of forest-product research and innovation findings. From 2008–2009 to 2011–2012, MRI invested $25.8 million in CRIBE.
Water Technologies Acceleration Project (WaterTAP)	Water technology companies	WaterTAP was established under the *Water Opportunities and Water Conservation Act* (2010) to help grow Ontario's water and wastewater industry. WaterTAP's mandate includes becoming a trusted source of information about Ontario's water sector, helping to identify research and commercialization opportunities, and developing international market intelligence. Since 2011–2012, MRI has invested $1.5 million in WaterTAP, with another $3.4 million committed for 2012–2013.

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Program	Eligibilty		Program Details and Funding
Direct business support			
Ontario Venture Capital Fund (OVCF)	- Business, direct - Access to capital	N/A	OVCF is a joint initiative between the Government of Ontario and leading institutional investors that include TD Bank, OMERS Strategic Investments, RBC, the Business Development Bank of Canada, and Manulife Financial. Announced in 2007, Ontario made an initial investment of $90 million in the OVCF, and has since leveraged it into a $205 million venture capital fund.
Innovation Demonstration Fund (IDF)	- Business, direct - Access to capital	Companies in the field of emerging green technologies	The IDF is a discretionary, non-entitlement funding program administered by MRI. Its purpose is to support companies in pilot demonstrations that will lead to commercialization. The program focuses on emerging green technologies. The funding potentially available from the IDF ranges from $100,000 to $4 million per project. Eligible costs could include: - start-up costs associated with the development and design of pilot demonstration prototypes; - equipment purchase, installation, and retrofitting costs; - direct labour costs for personnel involved in the project; - maintenance costs; - costs associated with training of skilled resources; and - monitoring and evaluation costs. Since its announcement in 2006, MRI has invested $73 million through the IDF.

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Program	Eligibilty		Program Details and Funding
Market Readiness Program	- Business, direct - Access to capital	Research institutions or their newly created start-up companies at the stage of pre-revenue and pre-investment	The four-year, $46-million Market Readiness Program assists the transfer of research from academia to an existing Ontario-based company. It does so by supporting key activities such as technology and market assessment, intellectual property protection, prototype development, and business plan development. OCE currently administers the program, which consists of three phases: **Phase I – Intake.** This covers the discovery stage where a proof-of-concept is established. Phase I investments are up to $75,000. **Phase II – Development.** This covers all stages of development, including the execution of developed plans, development of marketing and production plans, and the validation stage when the product is tested, customers are surveyed, and financial feasibility is determined. Phase II co-investments are up to $125,000 for development, or up to $150,000 for validation. **Phase III – Product Launch.** This covers all stages of launching a product, including marketing strategy execution, scalability of product and production/manufacturing process, personnel training, and engagement of first customers and potential follow-on investors. Phase III investments are up to $250,000.
Business Mentorship and Entrepreneurship Program	- Business, direct - Training		This program, administered by MaRS, helps talented entrepreneurs obtain the necessary management skills to take their new high-tech product or service through to the marketplace.
The Next Generation of Jobs: Biopharmaceutical Investment Program	- Business, direct - Access to capital	Pharmaceutical companies	This five-year initiative is designed to increase the level of biopharmaceutical research and development and advanced manufacturing in Ontario, and to help create high-quality jobs. Announced in 2009, to date MRI has invested $63 million through the program (Ontario Ministry of Finance).
Indirect business support			
Ontario Tax Exemption for Commercialization (OTEC)	Tax break	N/A	Announced in 2008, OTEC encourages commercialization of intellectual property developed at universities and colleges. It offers a refund of corporate income tax and corporate tax paid for a qualifying corporation's first 10 taxation years.

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Program	Eligibilty		Program Details and Funding
Ontario Innovation Tax Credit (OITC)		N/A	The OITC is a 10 per cent refundable tax credit available to all corporations that perform scientific research and experimental development in Ontario. The 2008 Ontario Budget proposal extended OITC to more small and medium-sized corporations and for more qualifying expenditures. MRI's 2012–2013 budget allocated $240 million to the OITC (Government of Ontario, 2013f).
Ontario R&D Tax Credit (ORDTC)		N/A	The ORDTC provides a 4.5 per cent tax credit based on eligible scientific research & experimental development (SR&ED) expenses carried out in Ontario (Government of Ontario, 2013f).
Ontario Business Research Institute (OBRI) Tax Credit		N/A	The OBRI tax credit provides a 20 per cent refundable tax credit to corporations that carry out SR&ED activities with Ontario research organizations. MRI's 2012–2013 budget allocated $9.7 million to OBRI (Government of Ontario, 2013f).
Ontario Interactive Digital Media Tax Credit		Digital media companies	This refundable tax credit is based on eligible Ontario labour expenditures and marketing and distribution expenses claimed by a qualifying corporation for development of interactive digital media products (Government of Ontario, 2013f).
Public procurement			
Green Focus on Innovation and Technology (GreenFIT)		Green technology companies	Through the GreenFIT procurement program, new green technology companies can introduce their innovative and sustainable solutions to the various departments of the Government of Ontario.
Green Schools Pilot Initiative (GSPI)		Clean tech companies	The GSPI provides Ontario clean tech companies with an opportunity to demonstrate the viability of their products and services to a well-known customer base: Ontario's schools.
Defunct programs			
Premier's Innovation Award (terminated in 2011)	- Academics, direct - Research awards	Full-time faculty of publicly funded research institutions	From 2007, MRI recognized innovation talents in Ontario through three awards: Premier's Catalyst Awards ($2.8 million to 14 innovative companies), Premier's Discovery Awards ($4.75 million to 13 top researchers), and Premier's Summit Awards ($20 million to 8 outstanding medical researchers).
Ontario Innovation Trust (terminated in 2009)	- Academics, direct - Support for public R&D activities	Full-time faculty of publicly funded research institutions	Since its creation in 1999, the Trust invested $849 million to enhance infrastructure for scientific research and technology development. It funded 1,253 projects at 44 Ontario universities, colleges, research hospitals, and other institutions.

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Program	Eligibilty		Program Details and Funding
Ontario New Technology Tax Incentive Gross-up (as of 2009 no longer in effect)			This tax deduction allowed 100 per cent write-off of the cost of intellectual properties acquired from third parties for the purpose of implementing an innovation or an invention in a company's business.
Ontario Commercialization Investment Fund	- Business, direct - Access to capital	Spinoff technology companies from research institutes	The program's purpose was to leverage seed capital for spinoff technology companies created by faculty, staff, or students of research institutes. From 2006–2007 to 200–2010, MRI invested $6 million through the fund.
Ontario Research Commercialization Program (ORCP)	- Academics - Commercialization	Public research institutions and not-for-profit organizations	Launched in June 2005, ORCP has helped Ontario's researchers and entrepreneurs combine their skills, expertise, and resources to commercialize their innovations. From 2006–2007 to 2008–2008, MRI invested $22.5 million in ORCP.

Appendix B

- This appendix calculates the expenditures of various Ontario innovation programs.

MRI Programs	2011–2012	2010–2011	2009–2010	2008–2009	2007–2008	2006–2007	TOTAL
Business Ecosystem Support Fund	12,340,000	14,146,000					26,486,000
Centre for Research and Innovation in the Bio-economy	6,285,000	9,000,000	7,500,000	3,000,000			25,785,000
Commercialization and Innovation Network Support	58,300,000	61,500,000	55,420,000				175,220,000
Grants in Support of Innovation and Commercialization	1,000	1,000	225,100	100,000	100,000	100,000	527,100
Innovation Demonstration Fund	16,900,000	19,733,500	15,733,500	8,900,000	5,900,000	6,000,000	73,167,000
Innovation Demonstration Fund — Interest Incentives	100,000	100,000	100,000	100,000	100,000		500,000
International Collaborations	3,500,000	1,000,000	1,500,000				6,000,000
Next Generation of Jobs Fund — Biopharmaceutical Investment Program	3,346,000	20,100,000	27,700,000	11,900,000			63,046,000

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MRI Programs	2011–2012	2010–2011	2009–2010	2008–2009	2007–2008	2006–2007	TOTAL
Next Generation of Jobs Fund — Interest Incentives	100,000	100,000	100,000	100,000			400,000
Ontario Emerging Technologies Fund	41,934,000	25,822,000	50,000,000				117,756,000
Ontario Life Sciences Commercialization Strategy	9,500,000						9,500,000
Social Innovation Generation	1,250,000	1,250,000	2,000,000	1,000,000			5,500,000
Water Technology Acceleration Project	1,500,000						1,500,000
Grants in Support of Science and Research	1,000	1,000	225,100				227,100
Ontario Brain Institute	6,590,000						6,590,000
Ontario Institute for Cancer Research	84,000,000	82,000,000	82,000,000	79,100,000	62,000,000	21,572,000	410,672,000
Ontario Research Fund	86,473,500	85,863,400	94,804,700	55,409,000	84,803,200	55,450,000	462,803,800

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MRI Programs	2011–2012	2010–2011	2009–2010	2008–2009	2007–2008	2006–2007	TOTAL
Ontario Spinal Cord Research Partnership	2,537,000	2,537,000	2,537,000	2,114,000			9,725,000
Perimeter Institute for Theoretical Physics	5,000,000					5,000,000	10,000,000
Research Talent Program	3,661,100	15,200,000	16,200,000	16,200,000			51,261,100
Science and Technology Connections and Partnerships	911,300	2,500,000	2,500,000	2,850,000	2,500,000		11,261,300
Ontario Research and Development Challenge Fund		235,000	4,664,300	19,770,200	29,000,000	53,728,000	107,397,500
Ontario Innovation Tax Credit	240,546,700	240,546,700	240,546,700	240,546,700	240,546,700	240,546,700	1,443,280,200
Ontario Commercialization Investment Fund			1,000,000	5,000,000	300,000	500,000	6,800,000
Ontario Genomic Institute			5,000,000				5,000,000
Ontario Venture Capital Fund				90,000,000	10,000,000		100,000,000

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MRI Programs	2011–2012	2010–2011	2009–2010	2008–2009	2007–2008	2006–2007	TOTAL
Social Venture Capital Fund				20,000,000			20,000,000
Business Mentorship and Entrepreneurship Program				4,950,000	3,800,000		8,750,000
Centre for International Governance Innovation				1,646,300	1,850,000	1,394,400	4,890,700
Centre for Research and Innovation in the Bio-economy				3,000,000			3,000,000
Investment Accelerator Fund				8,970,000	6,600,000		15,570,000
Ontario Centres of Excellence				34,300,000	34,300,000	34,300,000	102,900,000
Ontario Commercialization Network				4,890,000	6,450,000	5,900,000	17,240,000
Ontario Research Commercialization Program				7,938,100	7,654,400	7,000,000	22,592,500
Technology Innovation Program				4,090,000	2,840,000	3,750,000	10,680,000

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MRI Programs	2011–2012	2010–2011	2009–2010	2008–2009	2007–2008	2006–2007	TOTAL
Early Researchers Award					11,700,000		11,700,000
Post-doctoral Fellowship					2,000,000		2,000,000
Premier's Catalyst Awards					1,000,000		1,000,000
Premier's Discovery Awards					1,500,000		1,500,000
MaRS Discovery District					2,000,000	1,800,500	3,800,500
Commercialization — Entrepreneurship and Start-up Support						3,800,000	3,800,000
Commercialization — Market Readiness Program						5,600,000	5,600,000
Ontario Cancer Research Network						18,500,000	18,500,000
Premier Research Excellence Awards						2,600,000	2,600,000

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MRI Programs	2011–2012	2010–2011	2009–2010	2008–2009	2007–2008	2006–2007	TOTAL
Research Talent Development Program						9,100,000	9,100,000
TOTAL MRI	**584,776,600**	**581,635,600**	**609,756,400**	**625,874,300**	**516,944,300**	**476,641,600**	**3,395,628,800**
OMAFRA Programs							
Growing Forward — Economic Development	5,110,000	4,530,000	3,073,300				12,713,300
Growing Forward — Research	9,306,700	9,445,700	6,390,000				25,142,400
OMAFRA-University Guelph Research Partnership	59,805,000	59,805,000	59,650,000	59,600,000	54,800,000	54,800,000	348,460,000
TOTAL OMAFRA	**74,221,700**	**73,780,700**	**69,113,300**	**59,600,000**	**54,800,000**	**54,800,000**	**386,315,700**
TOTAL	**658,998,300**	**655,416,300**	**678,869,700**	**685,474,300**	**571,744,300**	**531,441,600**	**3,781,944,500**

Data source: Ontario Ministry of Finance, expenditure estimates from 2006–2007 to 2012–2013.

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