PARADOX LOST

Explaining Canada's Research Strength and Innovation Weakness

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

THE COUNCIL OF CANADIAN ACADEMIES

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Science Advice in the Public Interest

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MESSAGE FROM THE PRESIDENT

Science and technology, research and development, and innovation are the engines of every leading economy. To determine how best to leverage Canada's innovative capacity, today's policy-makers must rely on authoritative and accurate data on the opportunities and challenges to be found in both the private sector and academia.

Over the last several years, the Council of Canadian Academies has developed a portfolio of assessments on different aspects of Canada's S&T, R&D, and innovation performance. It is with pleasure that I now present the Council's inaugural synthesis report, which draws from the findings and insights of seven assessments: *The State of Science and Technology in Canada* (2006 and 2012), *Innovation and Business Strategy: Why Canada Falls Short* (2009), *Catalyzing Canada's Digital Economy* (2010), *Informing Research Choices: Indicators and Judgment* (2012), *Innovation Impacts: Measurement and Assessment* (2013), and *The State of Industrial R&D in Canada* (2013). By synthesizing the conclusions of these assessments into one brief yet comprehensive document, we attempt to provide a broad, up-to-the-minute perspective to better serve decision-makers as they navigate a global economy shaped by rapid technological change.

I must thank Peter Nicholson, Bob Fessenden, and Marcel Côté — the synthesis report's Advisory Group — for their tireless efforts and unwavering commitment to this project. Their analysis and expertise permit reports such as this one to inform policies that ultimately serve all Canadians.

Sincerely,

Elizabeth Dowdeswell, O.C.
President and CEO

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Executive Summary

The Council of Canadian Academies (the Council) has, since 2006, completed seven expert panel assessments analyzing in great depth Canada's performance in science and technology (S&T) and innovation. This document synthesizes the main findings of that work, from which two main conclusions emerge:

- Canadian academic research, overall, is strong and well regarded internationally.
- Canadian business innovation, by contrast, is weak by international standards, and this is the primary cause of Canada's poor productivity growth.

The conclusions are linked by a paradox. Why has Canada's research excellence not translated into more business innovation? The paradox is resolved once it is recognized that (i) most innovation does not work according to a "linear" model in which academic research yields a pipeline filled with ideas that, following some research and development (R&D), are commercialized by business; and (ii) business strategy in Canada is powerfully influenced by many factors besides those that motivate innovation. These factors include Canada's comparative advantage in a remarkably integrated North American economy, the state of domestic competition, the profitability of existing business models, and the particular Canadian attitude to business risk that has been shaped by the foregoing conditions.

There is a second paradox. How has Canada's economy sustained relative prosperity despite weak innovation and correspondingly feeble productivity growth? The answer is that Canadian firms have been as innovative as they have needed to be. Until the early 2000s, their competitiveness was supported by an ample labour supply and a favourable exchange rate, which made productivity growth less urgent. Since then, the boom in commodity prices has supported Canadian incomes in the aggregate. But a high-wage country like Canada cannot sustain its prosperity indefinitely without healthy productivity growth and its necessary prerequisite — an aggressively innovative business sector.

CANADA'S RESEARCH PERFORMANCE

Evaluations of Canadian research have consistently confirmed strong performance in most fields. This has become part of the conventional wisdom, and thus risks breeding a complacency that needs to be resisted. Canada must sustain its hard-won status as a global research leader because research excellence is essential to:

- underpin the production of highly qualified people, trained at the leading edge so as to enhance the innovative capacity of Canadian business;
- ensure that Canadians have "insider access" to the latest global knowledge pools since inclusion in the best international networks depends on the quality of one's contributions; and
- make Canada a stronger magnet for business investment in knowledge-intensive activity where ready access to world-class talent and facilities is a *sine qua non*.

Council reports on the state of S&T research in 2006 and 2012 developed an innovative methodology to assess Canada's strengths against global performance standards. A multi-lens perspective (bibliometrics, and domestic and international surveys) on the three principal dimensions of strength (i.e., publication output, quality/impact of the output, and trends in quantity and quality) was applied with unprecedented granularity at the level of individual research fields. The evaluation methodology provided the essential blend of quantitative and judgmental evidence needed to draw properly nuanced conclusions.

The State of Science and Technology in Canada, 2012 implicitly challenges the Canadian research community to debate its findings in each of the 20 major fields evaluated, and particularly the 176 sub-fields, and to suggest how the evaluation methods can be improved. The individual expert communities have a unique opportunity to better understand how their own fields are positioned internationally and within the Canadian research enterprise as a whole. This deeper understanding would provide Canada with the guidance and motivation to enhance its position among the world's research leaders.

CANADA'S BUSINESS INNOVATION PERFORMANCE

The Council's assessments of business innovation demonstrate the need for a fundamental change of paradigm away from a preoccupation with "R&D supply-push" and toward a *firm-centric* perspective emphasizing (i) the conditions that determine the health of the innovation ecosystem, i.e., the network of knowledge generators, facilitators, and policy-makers within which innovating firms are embedded; and (ii) the main factors that influence a firm's decision whether or not to choose innovation as a core business strategy. A focus on innovation inputs, like academic research and R&D, puts the cart before the horse. A firm must first decide that a commitment to innovation, and the investments required, makes business sense.

Business (or "industrial") R&D is undeniably an essential stage in many important kinds of innovation, certainly in manufacturing and increasingly in knowledge-intensive services. Understanding the source of Canada's persistently weak business R&D spending, as well as the reason for its unprecedented decline (as a percentage of GDP) since 2001, is therefore important. *The State of Industrial R&D in Canada* (2013) showed that the latter has been due to the steep reduction in the manufacturing sector's share of the Canadian economy since the end of the "tech boom."

Canada's traditional R&D gap relative to the United States is explained by the greater specialization of the U.S. manufacturing sector in higher-technology, R&D-intensive industries than is the case for Canadian manufacturing. This structural condition accounts for many of the issues that continue to confound the innovation policy dialogue in Canada, e.g., the relatively weak demand for graduates with advanced degrees in science and engineering, and the particular difficulty of connecting university research with business. These are *demand-side* problems for which *supply-side* solutions continue to be proposed. Unless and until highly R&D-intensive firms achieve much greater weight in Canada's economy, a shortage of business receptors will continue to frustrate supply-push policies.

The fundamental question remains as to why Canadian business has never shown much inclination to adopt innovation-focused business strategies. There appear to be three principal reasons:

- **Canada's role in an integrated North American economy** — The nation's comparative advantage has for generations been as an upstream supplier of both commodities and cost-competitive manufactured products in highly integrated value networks largely dominated by U.S. firms. Acquiring needed innovation from the United States has simply been easier and cheaper.
- **Size of the domestic market** — Small markets tend to support less innovation than large markets, but examples like Switzerland and Sweden prove that a small domestic market does not necessarily inhibit innovation. The key is that these countries are aggressive competitors in global markets — as they *had* to be. Many Canadian exporters, however, have been content with the U.S. market next door and to play an upstream or subsidiary role.
- **Commercial success of Canadian business** — Most significantly, Canadian business has prospered in its chosen niche. With little motivation to change a successful formula, many firms have settled into a "low-innovation equilibrium" that has conditioned business habits and ambitions. Canadian business behaviour cannot be expected to change unless the conditions that have sustained its profitable, low-innovation equilibrium change first.

In fact, those conditions *are* changing profoundly.

LOOKING FORWARD

Four key megatrends are destined to shape the competitive environment facing Canadian businesses, and the policy challenges for governments, for years to come:

- Declining growth rates in the United States and other highly developed economies, combined with the upsurge of competitive vitality in emerging markets, are shifting the locus of export opportunity (and import competition) from areas where Canada has always enjoyed a unique geographical and cultural advantage.
- The global, development-driven demand for resource commodities, particularly energy, is creating growing environmental challenges and volatile price swings. These destabilizing factors will drive worldwide research priorities aimed at developing new sources and/or substitutes, and challenge Canadian resource firms to become innovation leaders.
- S&T revolutions in information and communication technologies, and fields like genomics and nanotechnology,

are destined to invade all aspects of business and social life. To remain competitive, Canadian firms will have to be among the leaders in the innovative application of these technologies. They are not there now.

- Population ageing will tend to create worker shortages that force up labour costs, thus placing a growing premium on productivity growth and the innovation required to create it.

These megatrends have changed the game. Canadian business is, for the most part, ill prepared to play. Many firms operating at the cutting edge of global competition are already keenly aware of the challenges ahead. Others have an intellectual awareness, but not yet the visceral realization needed to motivate a meaningful change in strategy. But it is coming — fast.

Canada's fundamental challenge is to transform its commodity-based economy to one based on providing a greatly expanded number of markets with an increased variety of goods and services where firms must compete primarily through product and marketing innovation. And, as more Canadian firms, out of sheer necessity, develop strategies that focus on innovation, they will create a much more powerful "business pull" on Canada's strong S&T capacity.

The Council's work, summarized in this document, suggests that the conceptual framework governing innovation policy needs to shift from the prevailing paradigm of R&D supply-push to a demand-pull perspective centred on the firm, the innovation ecosystem, and the factors that determine the choice of business strategy.

In summary:

- Policy-makers and commentators need to acknowledge that the business innovation problem in Canada has a pedigree as old as the country itself.
- Canadian business has not become more innovative because it has been able to prosper without needing to do so.
- Now, business will have to embrace innovation-focused business strategies to compete and survive.
- This creates the conditions where public policies to support business innovation can be more effective than in the past because innovation policy objectives and business motivation will finally be aligned.

1

Canada's Innovation Paradox

In September 2006 the Council of Canadian Academies (the Council) published its first expert panel assessment, *The State of Science & Technology in Canada*, which provided the evidence base for the designation of the priority areas in the new federal government's science and technology strategy.[1] Since then, the Council has completed six more multidisciplinary expert panel assessments that have analyzed in great depth Canada's performance in science and technology (S&T) and innovation from several perspectives (see Box 1.1). This document synthesizes the main findings of that work.

BOX 1.1 Council Assessments of Science & Technology and Innovation

1. ***The State of Science and Technology in Canada*** (2006) provides an extraordinarily detailed analysis of Canada's strengths and weaknesses, relative to global benchmarks, in almost 200 fields of research and technology, and related infrastructure. The findings on major areas of strength have been incorporated in the federal government's 2007 S&T strategy as priority areas for support.
2. ***Innovation and Business Strategy: Why Canada Falls Short*** (2009) provides a deep analysis of business innovation and its relation to Canada's productivity growth over several decades. It analyzes the principal factors that determine whether or not an individual Canadian firm adopts an innovation-focused business strategy.
3. ***Catalyzing Canada's Digital Economy*** (2010) explores the puzzling weakness of Canadian business investment in information and communication technologies (ICTs; hardware, software, and systems), and links this to sub-par business innovation. The study identifies the barriers that discourage ICT investment by small and medium-sized enterprises, and proposes a program solution that strongly influenced the creation of the government's $80-million Digital Technology Adoption Pilot Program in 2011.
4. ***Informing Research Choices: Indicators and Judgment*** (2012) assesses global best practices for the use of quantitative indicators and expert judgment to inform the allocation, among fields in the natural sciences and engineering, of government support for research.
5. ***The State of Science and Technology in Canada, 2012*** (2012) updates and significantly extends the 2006 report, using leading-edge bibliometric analysis and a unique survey of more than 5,000 of the world's top-cited researchers to assess Canada's research performance in 20 major fields and 176 sub-fields across science, engineering, humanities, and the arts. The report includes data on the distribution of research strength by province, as well as a "technometric" assessment of Canadian patenting.
6. ***Innovation Impacts: Measurement and Assessment*** (2013) assesses the current state of knowledge and practice on assessment/measurement of the impact of government investment to foster business innovation. A firm-centric framework is developed that conceptualizes innovation as occurring within an ecosystem of multiple actors. Thus, an assessment of the full impact of an investment needs to take into account its impact on the relevant parts of the innovation ecosystem.
7. ***The State of Industrial R&D*** (2013) examines the magnitude and distribution, across industries and provinces, of business R&D and analyzes quantitatively the R&D intensity gap between the United States and Canada. (The report complements *The State of Science and Technology in Canada, 2012*.) Aerospace, ICT, oil and gas, and pharmaceutical and medical manufacturing are identified as Canadian industries with strong R&D intensity relative to global measures.

1 The priority areas in *Mobilizing Science and Technology to Canada's Advantage* (2007) were natural resources and energy, information and communications technologies, health and related life sciences and technologies, and environmental science and technologies.

BOX 1.2 Definitions of S&T and Innovation

Science and Technology (S&T) — The scope of S&T, as interpreted in Council assessments, encompasses disciplines in the natural and health sciences, the social sciences, the arts and humanities, and engineering, as well as the myriad connections between science and its applications in technology. The Council's first report on *The State of Science & Technology in Canada* (2006) addressed both research disciplines and technology sectors, whereas the 2012 report focused on research carried out by post-secondary institutions, government, and not-for-profits, and an analysis of patent data. Business R&D is the primary focus of *The State of Industrial R&D in Canada* (2013).

Innovation — Innovation is defined in the *Oslo Manual* of the OECD as "[…] the implementation of a new or significantly improved product (good or service), a new marketing method, or a new organizational method in business practices, workplace organization or external relations" (OECD/Eurostat, 2005). More intuitively, innovation is simply new or better ways of doing valued things. The latter captures the breadth of the concept. An innovation is much more than an idea or even an invention. These necessary precursors are not innovations until they are meaningfully applied in some valued economic or socio-cultural context.

Two principal conclusions, well buttressed by evidence, emerge:

- Canadian academic research, overall, is strong and well regarded internationally.
- Canadian business innovation, by contrast, is weak by international standards, and this is the primary cause of Canada's poor productivity growth.

Thanks in part to the Council's work, these conclusions are now broadly acknowledged. Divergent views remain, however, as to why Canadian business innovation is, on the whole, sub-par and what might be done about it.

The conclusions are linked by a paradox. Why has Canada's research excellence not translated into more business innovation? This puzzle has been a recurrent theme in Canadian policy analysis, and was described in the authoritative Lamontagne report more than four decades ago: "Since 1916 […] the main objective of Canadian science policy has been to promote technological innovation by industry […] Almost every decade since the 1920s has witnessed renewed attempts by successive governments to achieve it, but on the whole they have all failed." (Senate Special Committee on Science Policy, 1970).

The paradox arises from an implicit belief in a "linear" model of the innovation process in which high-quality research yields a pipeline filled with bright ideas that, following some research and development (R&D), are commercialized by businesses. This model is a crude and misleading picture of business innovation, but has led to public policies in Canada, and elsewhere, that have emphasized "research-push" with a related focus on business (or "industrial") R&D as the principal indicator of business innovation. One consequence is that academic research has been relatively well funded, particularly over the last 15 years, with the result that Canadian research is now considered to be world-class in most fields.

Council reports and other studies have shown, however, that while research-based scientific knowledge is necessary for some kinds of innovation, it is far from sufficient for an innovative economy. This is because roughly 80 per cent of most modern economies involves firms that perform little or no R&D, yet many of them innovate in terms of business models, processes, marketing, and organization. Even in firms that perform R&D, a direct, linear connection rarely exists between an academic discovery and a commercial product.

Two vitally important indirect linkages between research and innovation are the training of highly qualified people and the emergence of talent clusters around some universities. But research and innovation have very different objectives, procedures, and rewards. The essence was well captured by Kevin Lynch: "research is a process that transforms money into knowledge, and innovation is the process that transforms knowledge into money" (Lynch, 2012). Even in this shorthand, there is an echo of the linear model and the risk of drawing too tight a linkage from research to invention to innovation.

The paradox of why Canada's research excellence has not yielded comparable business innovation performance is resolved once it is recognized that (i) the linear model is not the way most innovation works, and (ii) business strategy in Canada is powerfully influenced by many factors besides those that motivate innovation. Examples of such factors include Canada's comparative advantage in a remarkably integrated North American economy, the state of domestic competition, the profitability of existing business models, and the particular Canadian business culture and attitude to risk that have been shaped by the foregoing conditions.

There is a second paradox. How has Canada's economy continued to do remarkably well relative to other advanced countries despite productivity growth near the bottom of the OECD league tables, and an innovation performance to match? The answer is that Canadian firms have been as innovative as they have needed to be. Their competitiveness was supported, until the early 2000s, by an ample labour supply and a favourable exchange rate, which made productivity growth less urgent. More recently, the demand from China and other emerging economies has caused commodity prices to boom, boosting average incomes in Canada and offsetting, in the aggregate, the impact of weakness in manufacturing.

This state of affairs can be sustained only so long as the prices and export volumes of commodities remain strong, and the strains caused by growing regional economic imbalances are tolerable. Neither condition is assured. In any event, a high-wage country like Canada cannot sustain its prosperity indefinitely without healthy productivity growth and its necessary prerequisite — an aggressively innovative business sector.

In the context of these introductory observations, the primary objectives of this document are to:

- stimulate debate and research about the metrics used to assess Canada's S&T and innovation performance so as to improve their appropriateness and accuracy, bearing in mind the aphorism that "what gets measured is what gets done;" and
- deepen the understanding of the nature and causes of Canada's sub-par business innovation performance with a view to informing effective public policies.

The remainder of the document is structured as follows:

- Chapter 2 synthesizes the evidence for Canada's strong research performance overall, emphasizing the methodology developed by the Council to assess performance at a fine-grained level. The assessment of strengths and weaknesses from several perspectives at the scale of individual disciplines is an innovation in itself, and represents the main value added of the Council's work in this area.
- Chapter 3 synthesizes evidence that quantifies the relative weakness of business innovation in Canada, and identifies the factors responsible for the R&D gap between the United States and Canada. The primary value added by the Council's work on innovation is its demonstration of the need for a fundamental change of perspective: a paradigm shift away from a preoccupation with *inputs* to innovation, like R&D, to an emphasis on the *outputs* of innovation, and on factors that influence firms to adopt innovation-focused business strategies.
- Chapter 4, in conclusion, distils some broad implications and questions for public policy from the evidence.

Figures and data from the original Council reports are used, and updated where newer information is available.

2

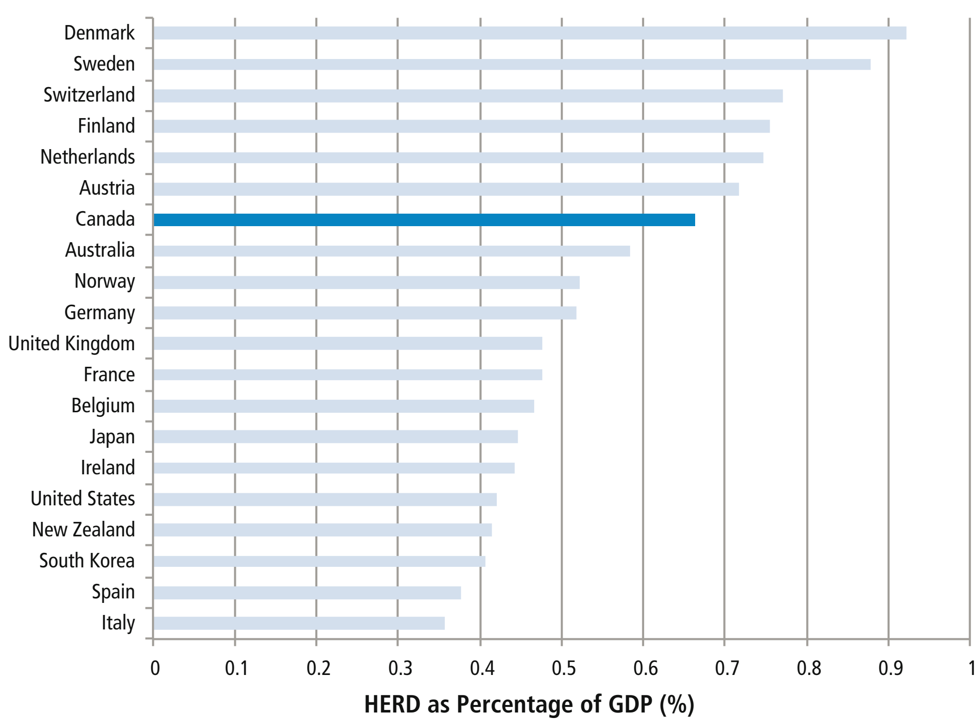
Canada's Academic Research Performance

The Council undertook, at the request of Industry Canada, detailed assessments of the state of S&T in Canada in 2006 and again in 2012, thereby establishing the beginning of a time series for periodically evaluating the nation's performance.[2] The studies are the most comprehensive assessments ever undertaken of the strengths (and weaknesses) of Canadian research in an international context. The principal conclusion of the two reports is that, overall, Canada's research is healthy, competitive, and highly regarded internationally.

The objectives of this chapter are to (i) describe the methodology used by the Council's expert panels to measure research performance, (ii) illustrate the method with a high-level summary of findings on Canada's strengths based principally on the 2012 report, and (iii) challenge the research community to debate the findings with a view to refining the methodology and developing a deeper understanding of how Canada's research performance can be improved continuously.

Exhibit 2.1

Expenditure on Higher Education R&D (HERD), 2011



	Average Annual Growth 2006-2011(%)
Denmark	9.6
Sweden	6.6
Switzerland	8.2
Finland	5.8
Netherlands	6.4
Austria	7.2
Canada	3.5
Australia	10.8
Norway	7.7
Germany	7.3
United Kingdom	3.6
France	5.5
Belgium	6.5
Japan	-0.8
Ireland	3.2
United States	5.2
New Zealand	6.4
South Korea	13.1
Spain	4.2
Italy	2.1

Canada regularly ranks high among spenders on R&D carried out in higher education institutions. But the trend in Canada's HERD intensity (HERD as a percentage of GDP) has been approximately flat since 2006. Average annual growth rates are in national currencies; 2006–2011 or latest available year.

Data source: OECD (2013) and Advisory Group calculations.

2 These assessments complement the *State of the Nation* reports issued every two years (since 2008) by the Science, Technology and Innovation Council, an advisory body to the Government of Canada.

CANADA'S INVESTMENT IN RESEARCH

Although the extent of a nation's financial support for research is actually an indicator of priority rather than a measure of strength, world-class research cannot happen without substantial and sustained investment. Expressed as a percentage of GDP, expenditure on R&D performed by Canada's higher education sector (HERD) regularly ranks in the top range of the global league tables (see Exhibit 2.1). In 2011 Canada's HERD was $11.4 billion, an increase of 18 per cent over the level of $9.6 billion five years earlier. Overall spending on R&D was approximately flat at $30 billion between 2006 and 2011, while spending on business R&D (BERD) actually declined by seven per cent to $15.3 billion by 2011.

Canadian R&D expenditure is marked by an unusually heavy concentration in the higher education sector. HERD made up 37 per cent of the total in 2009 compared with OECD and U.S. averages of 18 per cent and 14 per cent respectively. This is indicative both of the high priority Canadian funders placed on academic research and the chronic weakness of R&D performed by Canadian business (see Chapter 3).

MEASUREMENT OF RESEARCH PERFORMANCE

The two reports on the state of S&T in Canada (2006 and 2012) developed an assessment of strength against global performance standards, based on three principal dimensions: (i) *quantity* of research output, (ii) *quality/impact* of the output, and (iii) *trends* in quantity and quality. These dimensions were assessed from three perspectives or "lenses": bibliometrics (data on the amount and impact of published research), and surveys both of domestic and international experts. This provided the essential blend of quantitative and judgmental evidence needed to draw properly nuanced conclusions. Indeed, the assessment methods employed were consistent with the findings as to best practices in the Council's 2012 report, *Informing Research Choices: Indicators and Judgment* (summarized in Box 2.1).

BOX 2.1 Quantitative Indicators and Expert Judgment in Science Assessment

According to the Council's 2012 report, *Informing Research Choices: Indicators and Judgment*, many science indicators and assessment approaches are sufficiently robust to be used to assess research performance in the natural sciences and engineering at the level of nationally aggregated fields. No set of indicators or assessment strategy offers an ideal solution in research assessment for discovery research. And, because past performance is not always a strong predictor of future performance, science indicators, which are essentially measures of past performance, may not provide a reliable guide to future prospects.

Bibliometric indicators based on weighted publication counts and citation-based indicators (appropriately normalized by the field of research and based on a sufficiently long citation window) can be useful in assessing the overall scientific impact of the research. Advanced bibliometric approaches based on keyword analysis and identifying emerging clusters of highly cited research provide useful insights at a more detailed level. These can be used to flag active areas of research, which may span multiple fields, as targets for possible added support. Many other types of quantitative indicators, such as those based on the state and quality of available scientific infrastructure and equipment, can be used to characterize research trends or national research capacity.

It cannot be too strongly emphasized that quantitative indicators should be used to *inform* rather than *replace* expert judgment in science assessment for research funding allocation. For national research assessment at the field level, the weight of the evidence suggests the best approach is a combination of quantitative data and expert judgment.

The 2006 report, the first of its kind, assessed Canada's relative strengths in almost 200 fields of research and technology. Four broad domains were identified as areas of greatest Canadian strength: natural resources, information and communication technologies (ICT), health and related life sciences, and environmental S&T. Based on the Council's findings, these domains were subsequently adopted as the focus areas of the federal government's S&T strategy in 2007.

The Council's 2012 state of S&T report extended and refined the 2006 multi-lens methodology, applying it to 22 major fields[3] and 176 sub-fields of research covering virtually all disciplines across the natural, health, and social sciences; the arts and humanities; and engineering. The report included three main innovations.

3 Two of the 22 major fields dealing with "general S&T" and "general arts, humanities and social sciences" were analyzed but not included in most of the summary tables.

Exhibit 2.2

Indicators of Canadian Research Strength for Major Fields

The table summarizes 14 indicators of research strength for each major field. (The data are averages over 176 comprised sub-fields.) "Trends" are for the period 2005–010 compared with 1999–2004, except for the last two columns, based on the 2011 domestic expert survey, which refer to the prior five years.

	MAGNITUDE/INTENSITY			QUALITY/IMPACT		
Field	# of Papers (2005–2010)	Share of World Pubs. (2005–2010) (%)	SI (2005–2010)	ARC Score (2005–2010)	ARC Rank (2005–2010)	Share of Top 1% Cited Papers (%)
Agriculture, Fisheries & Forestry	15,880	5.33	1.38	1.25	8	7.90
Biology	18,227	5.23	1.18	1.34	7	5.45
Biomedical Research	31,326	4.96	1.12	1.18	9	4.22
Built Environment & Design	3,152	4.94	1.36	1.17	14	4.81
Chemistry	17,653	2.56	0.63	1.27	7	2.62
Clinical Medicine	88,354	4.09	0.98	1.59	3	6.15
Communication & Textual Studies	2,686	5.16	1.73	1.04	9	1.87
Earth & Environmental Sciences	15,788	5.79	1.23	1.29	9	4.53
Economics & Business	10,161	4.80	1.21	1.11	7	3.96
Enabling & Strategic Technologies	26,896	2.96	0.75	1.36	8	3.77
Engineering	34,927	3.92	1.01	1.37	6	4.44
Historical Studies	3,512	4.76	1.26	1.28	5	3.74
Information & Communication Technologies	40,529	4.35	1.12	1.30	6	4.27
Mathematics & Statistics	8,951	4.18	0.91	1.11	9	3.29
Philosophy & Theology	2,024	5.90	1.94	0.93	8	3.31
Physics & Astronomy	30,890	3.03	0.60	1.42	3	2.57
Psychology & Cognitive Sciences	12,319	7.64	1.96	1.13	5	5.39
Public Health & Health Services	15,298	6.88	1.82	1.24	7	8.00
Social Sciences	12,355	4.69	1.44	1.10	8	4.05
Visual & Performing Arts	286	3.71	1.37	2.09	2	4.55

QUALITY/IMPACT			TRENDS				
Canada’s rank in survey of top-cited international researchers	% of top-cited researchers identifying Canada in top 5	% of Canadian S&T experts rating field as strong	Change in share of world pubs (%)	Change in ARC	Change in SI	Gaining Ground (Canadian survey) (%)	Falling Behind (Canadian survey) (%)
2	57	78	-0.98	0.00	-0.31	7	19
5	37	57	-0.08	0.16	-0.11	5	16
5	37	62	0.36	0.07	0.03	8	18
5	29	50	-0.81	0.09	-0.26	10	7
7	20	53	-0.04	0.04	-0.03	6	29
4	43	55	0.40	0.10	0.04	7	16
4	58	55	0.09	0.13	-0.03	21	14
4	41	71	0.16	-0.02	-0.07	10	26
3	63	66	-0.23	0.05	-0.12	14	6
8	17	62	0.31	-0.05	0.06	13	21
7	27	70	-0.47	0.16	-0.16	8	17
5	35	53	0.21	-0.13	0.04	9	15
4	42	64	-0.71	0.13	-0.20	5	12
5	27	76	0.07	0.02	-0.01	24	15
3	79	65	0.73	0.05	0.20	12	6
7	19	56	0.34	0.16	0.05	8	10
3	69	67	0.52	0.04	0.03	15	4
3	58	65	0.78	0.07	0.18	26	10
3	54	60	0.18	-0.05	0.05	12	11
4	55	68	1.04	0.66	0.27	22	6

Notes: SI = Specialization Index; ARC = Average Relative Citations; ARC rank = Canada’s rank by ARC for 2005–2010. Other variables are drawn from the Survey of Top-Cited International Researchers and the Survey of Canadian S&T Experts.

Data source: CCA (2012a), Table 10.1

First, a web-based survey was conducted of the top one per cent most-cited authors in the world (2000–2008) in each of the 176 sub-fields, enquiring as to their assessment of the relative strength of Canadian research in their area of expertise. This elicited 5,154 responses from researchers in 40 countries, more than 70 per cent of whom had no prior direct association, through collaboration or study, with Canadian researchers. The international survey was complemented by a similar domestic survey that elicited 679 responses from pre-selected Canadian experts in academia, business, and government.

Second, an extensive analysis was carried out of a rich base of international bibliometric data (Scopus) covering 1999–2010, including almost 400,000 publications by Canadians in the 2005–2010 period. The standard analyses of average relative citation (ARC) ratios and specialization indices were supplemented with novel measures of collaboration involving Canadian researchers, interdisciplinary clustering, and emerging areas of intense research activity. (Results of the latter three innovative bibliometric analyses are included in the 2012 report, but will not be addressed here.)

Third, a common taxonomy of research fields was used to organize and analyze the survey and bibliometric data. This permitted direct comparison of the results via the different lenses.[4] (This had not been possible in the 2006 report.)

ASSESSMENT OF CANADA'S RESEARCH STRENGTHS

The data were used to construct indicators of the relative strength of Canadian research along dimensions of magnitude, quality/impact, and trend, using 14 indicators for the major fields and 10 for each sub-field. This original database, comprising more than 2,000 elements, thus provides a contemporary portrait of Canadian research that is of unprecedented depth and granularity. The matrix of indicators for the 20 major fields is reproduced in Exhibit 2.2. The complex picture conveyed by this table defies easy summary other than the conclusion that Canadian research in most disciplines is strong and well regarded internationally. Some highlights for each dimension of strength are outlined below.

Research Output:

- Canada ranks seventh in the world in the number of publications tracked in the Scopus database, and accounted for 4.1 per cent of the global total of 9.6 million research publications over 2005–2010. The United States and China lead with 26.7 per cent and 16.6 per cent respectively.
- Canada's publication total grew by almost 60 per cent between 1999–2004 and 2005–2010, making it the only G7 country to increase global share in the face of a more than three-fold growth in China's publication output.

Research Quality & Impact:

- Canadian publications, overall, have the world's sixth highest ARC ratio: 1.36 over 2005–2010, up from 1.27 in the previous five-year period.[5] Canada is ranked among the top 10 countries, by ARC, in all but 1 of the 20 major fields.
- Canadian authors account for 4.7 per cent of the top one per cent most-cited publications in the world, a proportion of the most influential papers that significantly exceeds Canada's 4.1 per cent share of all publications.
- Thirty-seven per cent of the top-cited international scholars surveyed ranked Canada among the top five countries in their particular fields. The United States was ranked in the top five by 94 per cent of respondents, the United Kingdom by 71 per cent, and Germany by 63 per cent.

These various measures testify both to the overall quality/impact of Canadian research as well as to its breadth across major fields.

Trends:

- According to the bibliometric indices of output and impact, Canada gained ground in most major fields between 1999–2004 and 2005–2010, i.e., 13 of the 20 increased their share of world publications and 16 had a higher (or equal) ARC ratio.
- On the other hand, in the case of 11 of the 20 major fields, a larger percentage of the domestic experts surveyed

4 The bibliometric analysis, as well as identification of top-cited researchers, was carried out for the Expert Panel by Science-Metrix. The opinion surveys were managed by EKOS Research Associates.

5 Canada's ARC for a field is the average number (per paper) of citations to Canadian papers in the field divided by the average number (per paper) of citations to *all* papers in the field. An ARC greater than 1.0 signifies a citation impact above the world average.

Exhibit 2.3
Surveyed Opinion on the Overall State of Canadian S&T

	Strong (%)	Average (%)	Weak (%)	Gaining Ground (%)	Stable (%)	Losing Ground (%)
2006	46	28	26	28	33	39
2011	57	29	14	15	35	50

Data source: CCA (2012a), Table 5.4

believe that Canadian research has been falling behind, rather than gaining ground, over the past five years (see the last two columns of Exhibit 2.2). For example, a significant proportion (29 per cent) saw Canadian research in chemistry falling behind, while only 6 per cent believed it was gaining ground. (A majority of 65 per cent saw the trend as neutral.) Public health & health services was at the other extreme with 26 per cent of the domestic expert sample believing that Canada was gaining ground while only 10 per cent saw a declining trend.

The domestic expert surveys in both 2006 and 2011 enquired as to the overall strength of Canadian research, as well as whether it had been gaining, falling behind, or holding steady over the previous five years. The results, summarized in Exhibit 2.3, indicate that Canadian research is now perceived to be stronger (2011 versus 2006), but a considerably greater percentage in the latest survey see Canada losing ground (50 per cent) than gaining (15 per cent). The exceptionally rapid rise of China as a research powerhouse is now likely influencing a perception of relative decline in countries already at or near the top, like the United States and Canada.

How consistent are the assessments of strength based on (i) bibliometric versus survey data, and (ii) international versus domestic expert opinion? Regarding (i), fields in the natural and health sciences and engineering generally showed a close correlation between quantitative and judgmental indicators, whereas fields in the arts and humanities often produced significant divergence between the bibliometric and survey results. Since scholarship in the latter fields is not predominantly expressed through academic journals, bibliometric evidence is relatively sparse and often unrepresentative. Peer judgment is therefore a more reliable gauge of strength in these domains. Regarding (ii), there was reasonable concordance between international and domestic assessments of Canadian strength, though a higher percentage of the top-cited authors rated Canada as strong assigning ratings of 5, 6, or 7 on a 7-point scale in 17 of the 20 major fields.

Can one distil from the wealth of data those fields in which Canada has particular strength? Exhibit 2.2 demonstrates that none of the 20 major fields ranks first (or last) on all indicators. Depending on one's perspective, some indicators will be more relevant than others. Finally, there are inevitable sampling biases in the data, and some of the sub-field indicator samples are too small to warrant much statistical confidence.

The Expert Panel in 2012 accorded particular weight to the global ranking of a field's ARC score, and the percentage of the international survey respondents that placed Canada among the top five countries in their particular field. Based on these criteria, 6 of the 20 major fields were identified as "research fields in which Canada excels": clinical medicine, historical studies, ICT, physics and astronomy, psychological and cognitive sciences, and visual and performing arts (listed in alphabetical order).

Of these, ICT, clinical medicine, and psychological and cognitive sciences are components of two of the four broad areas also identified as being of greatest Canadian strength in the 2006 report, i.e., ICT and health and related life sciences. Although the field taxonomies used in the 2006 and 2012 reports are not strictly comparable, it appears from results at the sub-field level in the 2012 assessment that Canada's *relative* strength in the other two broad domains identified in 2006, natural resources and environmental S&T, have declined somewhat since that time. Canadian research in those two domains continues to be strong and well regarded internationally, but certain

Exhibit 2.4
Indicators of Research Strength in Natural Resources and Environmental Disciplines

Field/Sub-Field	# of Papers	Share of World Pubs. (2005–2010) (%)	Change in Share of World Pubs. (%)	Survey Rank	ARC Score (2005–2010)	Change in ARC
Agriculture, Fisheries & Forestry	**15,880**	**5.33**	**-0.98**	**2**	**1.25**	**0.00**
Agronomy & Agriculture	3,300	4.47	-1.65	4	1.18	0.08
Dairy & Animal Science	2,091	4.11	-0.64	3	1.64	0.23
Fisheries	2,406	8.59	-1.18	1	1.31	-0.11
Food Science	1,862	3.85	-0.44	5	1.13	-0.01
Forestry	3,301	10.40	-1.95	2	1.12	-0.06
Horticulture	391	4.29	0.29	9	0.76	-0.23
Veterinary Sciences	2,529	4.51	0.02	3	1.31	-0.03
Earth & Environmental Sciences	**15,788**	**5.79**	**0.16**	**4**	**1.29**	**-0.02**
Environmental Sciences	3,729	4.81	-0.60	4	1.53	-0.08
Geochemistry & Geophysics	4,130	5.42	0.41	7	1.21	-0.15
Geology	1,681	10.45	-1.11	4	0.99	-0.12
Meteorology & Atmospheric Sciences	5,301	6.15	1.01	6	1.30	0.14
Oceanography	947	5.69	1.11	7	1.23	-0.13
Engineering	**34,927**	**3.92**	**-0.47**	**7**	**1.37**	**0.16**
Environmental Engineering	3,537	6.59	0.30	6	1.17	-0.09
Geological & Geomatics Engineering	2,748	5.69	-1.36	3	1.38	0.14
Mining & Metallurgy	1,428	3.95	-0.51	6	1.84	-0.19
Canada	**395,369**	**4.10**	**0.13**	**4**	**1.36**	**0.09**

The three major fields, and 15 sub-fields included in the table (with the all-fields average for comparison), are comparable to the research disciplines encompassed by "natural resources" and "environmental S&T" in CCA (2006). The field taxonomies and bibliometric sources in the 2006 and 2012 reports on the state of S&T in Canada differ somewhat; and the 2006 report also included areas of applied technology, which added considerably to the assessed strength of the natural resources domain in the earlier report. ARC = Average Relative Citations. The "Survey Rank" is Canada's global ranking as measured by the percentage of top-cited researchers who place Canada in the top 5 countries in the researcher's field.

Data source: CCA (2012a), Table 10.2

indicators (e.g., trends in ARC ratios and share of global publications) point to some weakening between the 2006 and 2012 reports (see Exhibit 2.4).

THE CHALLENGE TO CANADA'S RESEARCH COMMUNITIES

Evaluations of Canadian research have consistently confirmed strong performance in most fields relative to international benchmarks. This has become part of the conventional wisdom and thus risks breeding complacency, particularly as the primary attention of policy-makers shifts, not inappropriately, to Canada's shortcomings in business innovation and productivity growth (see Chapter 3). Any tendency toward complacency needs to be resisted. Canada must sustain its hard-won status as a global research leader because research excellence is essential to:

- underpin the continued production of highly qualified people, trained at the leading edge, so as to enhance the innovative capacity of both new and established firms in Canada;
- ensure that Canadians have "insider access" to the latest global knowledge pools since inclusion in the best international networks depends on the quality of one's contributions; and
- make Canada a stronger magnet for business investment in knowledge-intensive activity where ready access to world-class talent and facilities is a *sine qua non*.

How can the Council's work summarized here advance this endeavour? The top-line finding that Canadian research is strong is certainly not a new insight. What is new and significant is the innovative methodology developed to evaluate Canada's research strengths. A multi-lens perspective (bibliometrics and domestic and international surveys) on the three principal dimensions of strength (i.e., publication output, quality/impact, and trend) was applied with unprecedented granularity at the level of individual research fields.

The Council's 2012 report implicitly challenges the Canadian research community to debate its findings in each of the 20 major fields evaluated, and particularly the176 sub-fields.[6] The expert communities in each field should address at least the following questions:

- Are the assessments of strength (or weakness) in their field broadly valid?
- If not, where is the methodology deficient and how might it be improved next time?
- Where the findings are judged to be valid, how can the strengths be sustained and the weaknesses ameliorated?

The challenge to each of the expert communities contains a unique opportunity to better understand the large-scale dynamics in their own field as well as its position internationally and within the Canadian research enterprise as a whole. This deeper understanding, which should periodically be tested and refined in future Council studies, will provide Canada with both the guidance and the motivation to enhance its position among the world's research leaders.

6 Sub-field assessments can be found in the full report on the Council's website (www.scienceadvice.ca) and the raw data are available upon request.

3

Canada's Business Innovation Performance

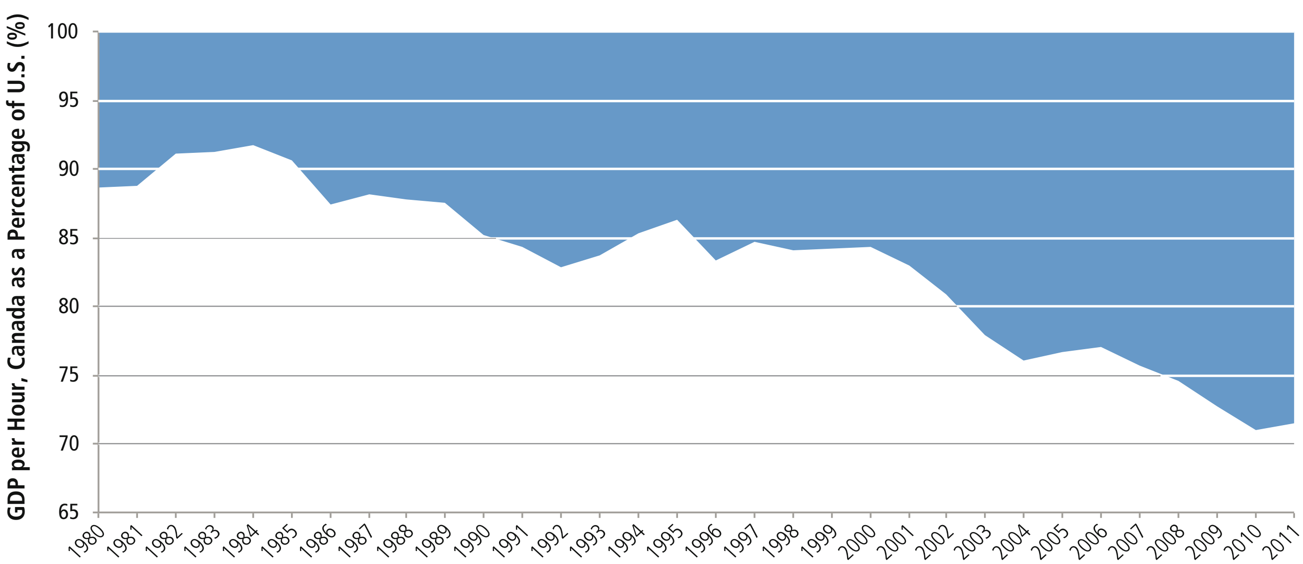
The economic significance of business innovation is due to its close linkage to labour productivity growth, which is the increase of the output of goods and services per hour worked. In the words of Nobel laureate Paul Krugman (1990): "Productivity isn't everything, but in the long run it's almost everything." While economic progress overall depends on productivity growth, the well-being of individuals clearly also depends on the distribution of the fruits of higher productivity, but that is a different subject.

The growth of labour productivity in Canada's business sector (which accounts for about 75 per cent of GDP) has been exceptionally weak, averaging 0.8 per cent per year between 2001 and 2011, and ranking 15th among 20 peer countries in the OECD.[7] It is of particular concern that Canada's labour productivity has declined from more than 90 per cent of the U.S. level in the mid-1980s to only 71 per cent in 2011 (see Exhibit 3.1). Combined with the strength of the Canadian dollar, this has significantly increased Canada's relative unit labour costs and reduced trade competitiveness, notably in manufacturing.

What has been responsible for the growing productivity gap in Exhibit 3.1? Statistics Canada has analyzed the evolution

Exhibit 3.1

Labour Productivity Levels in the Business Sector, Canada as a Percentage of the United States, 1980–2011



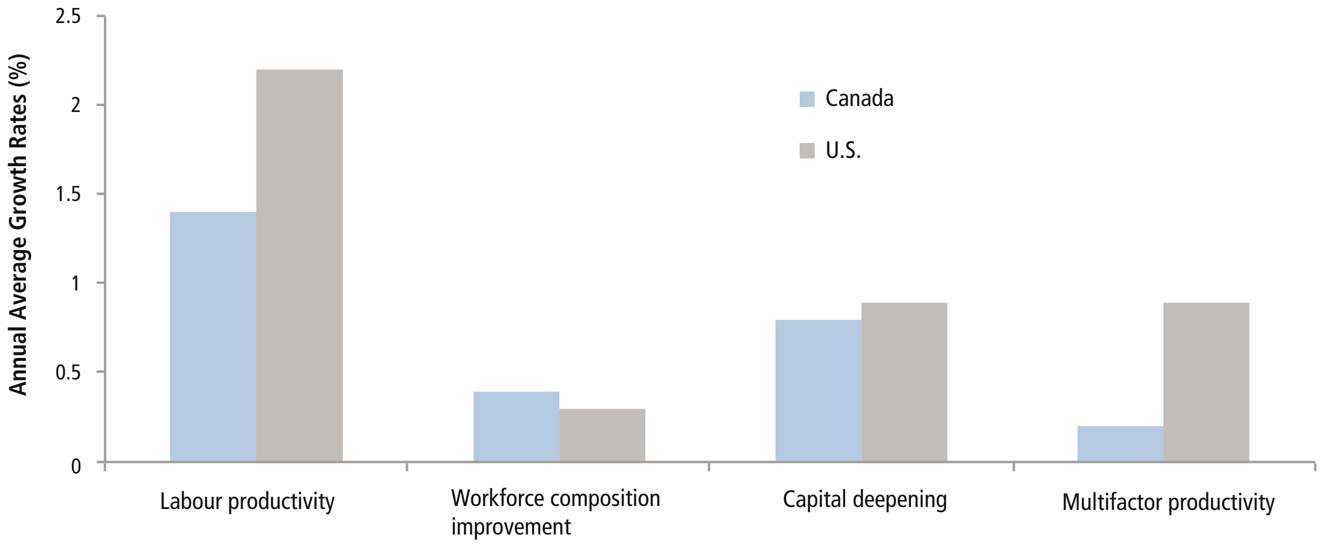
Canada's business sector labour productivity (GDP per hour) has been declining relatively, from more than 90 per cent of the U.S. level in the mid-1980s to only about 71 per cent by 2011. The relative decline has been particularly striking since the end of the "tech boom" in 2001. Meanwhile, job growth in Canada has been more rapid than in the United States despite the substantial strengthening of the Canadian dollar since 2002, which would be expected to encourage substitution of capital for labour.

Data source: CSLS (2013)

7 The peer group of 20 larger, highly developed countries used in this document as a base for international economic comparisons comprises the G7, the four Scandinavian countries, Australia, Austria, Belgium, Ireland, South Korea, Netherlands, New Zealand, Spain, and Switzerland.

Exhibit 3.2

Sources of Labour Productivity Growth, Canada and the United States, 1980–2011



The annual average rate of growth of labour productivity in the business sector in Canada and in the United States is equal to the sum of the respective national growth rates of the contributions of (i) improvement in the education and experience ("workforce composition"), (ii) capital employed per hour worked ("capital deepening"), and (iii) the MFP residual (see text). The data incorporate adjustment of previous estimates by Statistics Canada so as to align more closely with U.S. methodology. (See also Box 3.1.)

Data source: Baldwin & Gu (2013)

of the gap and decomposed it into three components due to U.S.-Canada differences in the growth rates of (i) the productive "quality" of the workforce (based on measures of education and experience); (ii) the productive contribution of capital; and (iii) multifactor productivity (MFP), which will be described below. Exhibit 3.2, based on a recently updated analysis by Statistics Canada (May 2013), shows that on average, between 1980 and 2011, both workforce quality and capital intensity increased at approximately the same average rates in Canada and the United States. Therefore, Canada's labour productivity shortfall has been entirely due to very weak MFP growth.

THE SIGNIFICANCE OF MULTIFACTOR PRODUCTIVITY

What does MFP actually measure? Since it is determined residually as the portion of labour productivity growth that is *not* due to labour quality or capital intensity, it encompasses a grab bag of factors including the effect of scale economies; the business cycle and capacity utilization; measurement errors; and, most significantly, the impact on productivity of working smarter, i.e., innovating.[8] When the focus is on the difference in MFP growth between Canada and the United States over long periods of time, it is likely that the factors that influence MFP, other than innovation, largely cancel out. That is why the Council's Expert Panel on Business Innovation concluded that Canada's sub-par productivity growth was due to weak business innovation. (Recent debate over the measurement of MFP is summarized in Box 3.1.)

MFP is a key statistic because it is a measure of outcome, as well as of innovation in the broad sense and not just its technological aspects. Virtually all other commonly reported indicators of Canadian business innovation (e.g., R&D; patenting; investment in machinery and equipment, especially in ICT) point in the same direction as the MFP statistics.[9] But these other indicators are more limited since

8 For example, when a fast food outlet puts in a drive-through window, revenue increases significantly while labour and capital inputs increase only a little. Customers' cars become extensions of the store, and most of the additional output shows up as MFP. More generally, MFP measures the impact on labour productivity of advances in the application of technology, managerial efficiency, and industrial organization.

9 Canada accounts for only 1.1 per cent of world patents, compared with 4.1 per cent of research publications. Much more significant for innovation and productivity is Canada's large and persistent gap, relative to the United States (and also several other advanced countries), in annual ICT investment per worker. This has averaged only 60 per cent of the U.S. level over the last 25 years. The investment gap has closed for computers, but increased for software, now the focus of innovative applications to boost business productivity and create entirely new capabilities. The reasons for Canada's relatively weak ICT investment are not well understood (Sharpe & Rai, 2013).

BOX 3.1 Debating the Measurement of Multifactor Productivity Growth in Canada

An important paper by Erwin Diewert and Emily Yu in the Fall 2012 issue of the *International Productivity Monitor* argues that the methodology Statistics Canada has used to analyze the components of labour productivity growth results in a significant underestimate of long-term MFP growth in Canada — specifically an average rate of only 0.3 per cent per year from 1961 to 2011 compared with 1.0 per cent according to the estimation method proposed by Diewert and Yu (2012). If the latter is correct, some might infer that Canadian business does not have such a serious business innovation problem after all.

Statistics Canada and Diewert-Yu do *not* differ to any meaningful extent in their estimates of Canadian labour productivity growth, and this is the important bottom-line metric in the context of economic well-being. They differ only in the proportions of labour productivity growth that are accounted for by MFP and by capital intensity. The different estimates arise principally from highly technical considerations involved in the measurement of capital services, specifically the appropriate way to estimate the "user cost of capital." There are acknowledged weaknesses in the approaches of both Diewert-Yu and Statistics Canada.

The Council's *Innovation and Business Strategy* (CCA, 2009) report focused on the *relative* weakness of Canada's MFP growth compared primarily with the United States, but also with other OECD countries. (Since the Diewert-Yu paper does not re-estimate MFP growth in the United States or other comparator countries, it does not address the key issue of Canadian MFP growth relative to international benchmarks.) John Baldwin and Wulong Gu (2013) of Statistics Canada subsequently re-estimated the components of labour productivity growth in Canada using methodology that matches more precisely that used by the United States. (Exhibit 3.2 is based on these new estimates.)

While the decomposition of labour productivity growth into MFP and capital components is illuminating, innovation is reflected in both MFP and in the use of capital. Capital becomes more productive as it embodies innovation, and businesses must innovate to adapt and employ new capital effectively. The microchip, for instance, is of no inherent productive value until it is used, for example, in new business models like Amazon and Google, or in "big data" applications that enable innovative marketing strategies. Thus the *disembodied* type of innovation measured, however imperfectly, by MFP, and the *embodied* innovation included in the flow of capital services, are complementary aspects of the common phenomenon of technical progress.

While the analytical debate over the estimation of MFP and the other components of labour productivity will continue to illuminate, the Council's central conclusion that Canadian business strategy has lacked a strong focus on innovation is not in doubt.

they are either inputs to, or intermediate stages of, the innovation process, and, with the notable exception of ICT, are relevant principally to certain sectors like manufacturing and its related knowledge-based services.

Nevertheless, indicators like R&D are symptomatic of business's commitment to an innovation-based strategy in the relevant industries. Also, much of the innovation policy dialogue continues to take place in the context of business expenditure on R&D. While that needs to be broadened, it is still important that the right messages are taken from the data.

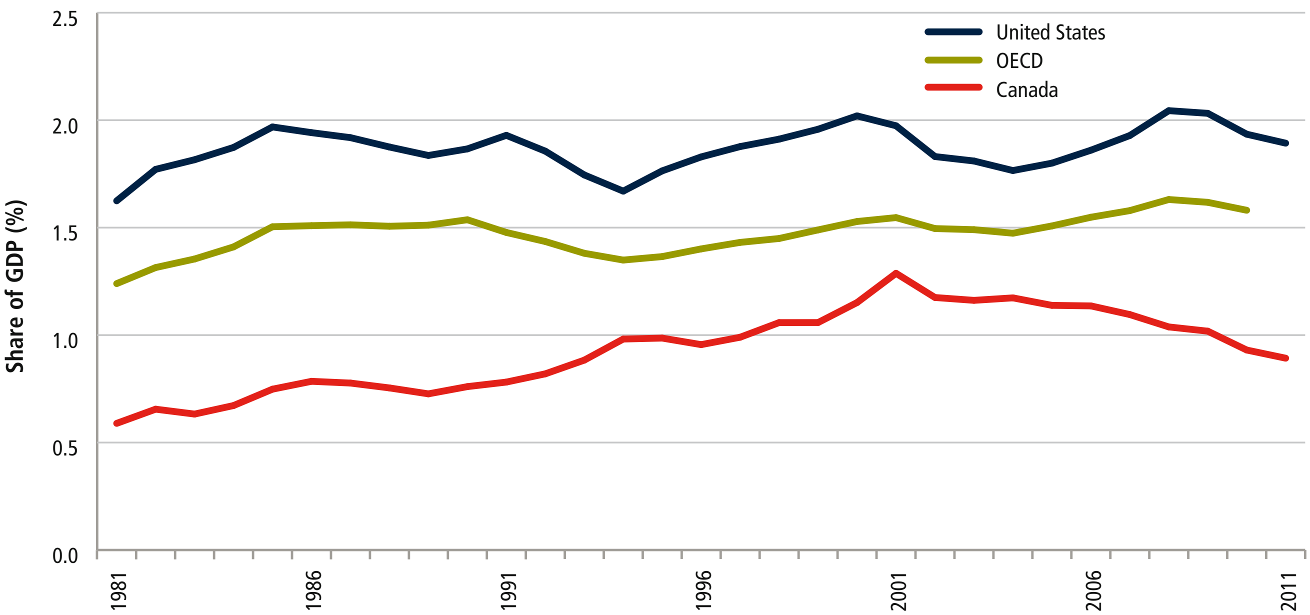
BUSINESS RESEARCH AND DEVELOPMENT

R&D spending in Canada, relative to GDP, has always been well below the OECD average. Following the end of the "tech boom" in 2001, it has been declining not only as a percentage of GDP (see Exhibit 3.3), but also in constant dollars. In 2011 business R&D spending in Canada was $15.3 billion or 0.9 per cent of GDP as compared, for example, with 1.9 per cent in the United States, 2.3 per cent in Sweden, and 1.3 per cent in Australia (like Canada, a resource-based economy).

What accounts for the decline in Canada's BERD intensity since 2000? Data from the Council's 2013 report, *The State of Industrial R&D in Canada*, show that the drop in BERD (as a percentage of business sector GDP) from 1.61 per cent in 2000 to 1.44 per cent in 2008 was due almost entirely to a sharp reduction in the manufacturing sector's share of the business economy from 24.4 per cent to 15.0 per cent (see Exhibit 3.4).[10] Because manufacturing is by far the most

10 Manufacturing output, in current dollars, declined from about $185 billion in 2000 to $175 billion in 2008 as the end of the tech boom and the 2008 recession took a particularly heavy toll on technology-intensive sectors in Canada. Business sector GDP as a whole increased by more than 50 per cent since 2000.

Exhibit 3.3
Business R&D Intensity, 1981–2011



Canadian business was closing the R&D gap until the end of the "tech boom" in 2001. Since then, Canadian BERD intensity has declined.

Data source: CCA (2013a), Figure 2.2

R&D-intensive sector, the steep fall in its share of output reduced overall BERD intensity by about 0.43 percentage points.[11] Although BERD intensity actually increased significantly both in services and in mining and oil and gas extraction, Exhibit 3.4 shows that these positive changes were not nearly enough to offset the effect of the structural decline in manufacturing.

A similar analysis shows that the large and persistent gap between U.S. and Canadian BERD intensities is due to the much higher BERD intensity of the U.S. manufacturing sector: 9.7 per cent versus 4.5 per cent in Canada in 2006, the latest year for which comparable data are available (see Exhibit 3.5). Canada actually had a slight structural advantage in 2006 since manufacturing constituted a larger share of the Canadian economy. Significantly, the resource extraction sectors explain very little of the U.S.-Canada BERD gap because, despite a much larger share of the Canadian economy, they have intrinsically low BERD intensities and therefore account for only a small proportion of BERD in both countries.

Further insight is gained when manufacturing is subdivided into industries that the OECD has classified as high, medium and low technology. U.S. manufacturing is much more heavily weighted to the high- and medium-technology activities, which have intrinsically high BERD intensity. Canada, however, has a much higher proportion of low-technology activities (including, for example, resource-based processing), where BERD intensity is inherently very low.

The impact of foreign ownership on Canadian BERD depends on the industry. For example, auto assemblers and foreign-owned chemicals manufacturers perform relatively little R&D in Canada, whereas BERD ratios in foreign-owned computer and pharmaceutical firms are comparable to those in the United States. The problem, therefore, is not foreign ownership, *per se*. Canada's business R&D shortfall is due to the fact that highly R&D-intensive industries make up only a relatively small share of Canada's economy.

This structural condition accounts for many of the issues that dominate and confound the innovation policy dialogue in Canada, e.g., the relatively weak demand for graduates with advanced degrees in science and engineering, and the particular difficulty of connecting university research with business. These are *demand-side* problems for which *supply-side* solutions continue to be proposed. Unless and until

11 BERD intensity for the economy is the sum of the BERD intensities for each sector (e.g., about 4.5 per cent for manufacturing) multiplied by the sector's share of GDP.

Exhibit 3.4

Accounting for BERD Intensity Change in Canada, 2000–2008

Sector	Share of the business sector		R&D intensity		Contribution of sector to change in R&D intensity
	2000	2008	2000	2008	
	%	%	%	%	Percentage points
Agriculture, forestry, fishing & hunting	2.88	2.41	0.42	0.48	0.00
Mining and oil & gas extraction	7.91	13.37	0.30	0.63	0.07
Utilities	3.41	2.98	0.64	0.63	0.00
Construction	6.45	9.3	0.10	0.11	0.00
Manufacturing	24.36	15.01	4.52	4.45	-0.43
Services	55.00	56.92	0.81	1.13	0.20
Business sector	**100**	**100**	**1.61**	**1.44**	**-0.17**

Canada's BERD intensity (business R&D as a percentage of business sector GDP) declined by 0.17 percentage points between 2000 and 2008. The sharp drop in the GDP share of the manufacturing sector was largely responsible. The BERD intensity of manufacturing declined only slightly, while services and mining contributed positively to the change in BERD intensity.

Data source: CCA (2013a), Table 2.3

Exhibit 3.5

Accounting for the Canada – U.S. BERD Intensity Gap, 2006

Sector	Share of value added (%)		BERD Intensity (%)		Contribution of sector to BERD gap
	Canada	United States	Canada	United States	Canada minus U.S. (percentage points)
Business sector	100	100	1.22	1.85	-0.63
Agriculture, forestry, fishing & hunting	1.6	0.9	0.5	–	0.01
Mining & quarrying	8.6	1.7	0.6	–	0.05
Manufacturing	14.6	13.3	4.5	9.7	-0.63
Electricity, gas & water supply	2.5	1.8	0.9	0.1	0.02
Construction	6.5	4.9	0.1	0.2	0.00
Services	66.2	77.4	0.7	0.7	-0.08

U.S. BERD intensity has always exceeded that of Canada — in 2006 by 0.63 percentage points. The gap is accounted for largely by the much higher BERD intensity of U.S. manufacturing (more than double that of Canada). U.S. data for the two resources sectors are suppressed for confidentiality reasons and have been set to zero. They make only a very small contribution to U.S. BERD intensity.

Data source: CCA (2013a), Tables 2.4 and 2.5

BOX 3.2 Looking Behind the R&D Data

The Council strives to assemble a reliable base of evidence to inform its assessments, which usually requires looking behind the numbers to ensure their proper interpretation. *The State of Industrial R&D in Canada* (2013) includes an important appendix that describes several data challenges that complicate the interpretation of R&D statistics and their cross-country comparison.

According to Exhibit 3.6, for example, wholesale trade accounts for 8.4 per cent of Canadian business R&D, but some unknown, though likely substantial, portion is actually attributable to manufacturing industries (probably pharmaceuticals and elements of ICT). This can happen because Statistics Canada assigns R&D expenditure to the industry that accounts for the majority of the R&D performer's activity. If the Canadian enterprise is primarily engaged in distribution and sales, but also performs R&D, the R&D expenditure would be assigned to wholesale trade even though it may relate to manufacturing carried out abroad, e.g., by a parent corporation or an "off-shored" factory. This anomaly, which has become more frequent with the globalization of production, led the United States in 2004 to begin assigning R&D to the related manufacturing industry rather than to wholesale trade. Canada has not yet followed suit.

Scientific research and development services, now the largest BERD performer in Canada, includes R&D related to a wide range of fields in the natural, social, and life sciences. Many countries, but not yet Canada, assign this R&D to the products or industries it serves, which is clearly preferable for analytical purposes.

The proper assignment of R&D (and other data relating to the innovation process) to relevant industry categories will always be challenging because the appropriate categories are a moving target as technology and the nature of business activity evolve, e.g., the old boundaries between manufacturing and many services have become completely blurred. In this context, international harmonization of statistical practices (through the OECD) should be an ongoing priority. There will, nevertheless, always be the need to look carefully behind the numbers before leaping to conclusions. In our data-saturated world, this principle is too rarely followed.

highly R&D-intensive firms achieve much greater weight in Canada's economy, a shortage of business receptors will continue to frustrate "supply-push" policies. (Recall the quotation in Chapter 1 from the 1970 Lamontagne report.)

This begs the question as to which industries in Canada today appear to have substantial strength on which to build.[12] *The State of Industrial R&D in Canada* (2013) includes a fine-grained analysis of 17 industries that account for more than 80 per cent of business R&D and 90 per cent of patents in Canada, as well as for about 23 per cent of GDP (see Exhibit 3.6). Based on the array of indicators related to R&D, patents, and economic weight (and their trends), Canada's primary technology-based strengths lie in ICT, aerospace, and pharmaceuticals. Scientific R&D services is a large and fast-growing R&D performer, but is a heterogeneous collection of sophisticated services mainly to other industries. Wholesale trade is an anomalous member of the group, and the surprising size of its R&D expenditure appears to reflect classification issues (see Box 3.2). The oil and gas extraction industry is an interesting special case. Although it has very low BERD intensity (0.7 per cent) and share of patents (0.5 per cent), its R&D spending has increased almost four-fold since 2001, and its patents are very highly cited (almost three times the world average in the industry.) The extremely dynamic growth of oil and gas appears to have triggered a strong commitment to innovation.

A FIRM-CENTRIC PERSPECTIVE ON INNOVATION

R&D is undeniably an essential stage in many important kinds of innovation, certainly in manufacturing and increasingly in knowledge-intensive services. But the stubborn tendency to equate R&D and business innovation continues to inhibit a deeper understanding of innovation and the development of more effective public policies to facilitate it.[13] The truth is that Canada's low business R&D spending is a *symptom* rather than a *cause* of weak business innovation.

Two Council reports, *Innovation and Business Strategy: Why Canada Falls Short* and *Innovation Impacts: Measurement and Assessment*, have addressed the issue from different but

12 What follows addresses industries that show current technological strength. Entirely new industries, however, can emerge almost overnight and generate large firms quickly, as has happened in many areas of ICT.

13 Business investment in R&D is only one component of investment in intangible assets such as software, databases, mineral exploration, design engineering, advertising, training, and organizational change. Investment in such intangibles in Canada was $150 billion in 2008, about two-thirds of business investment in tangible assets. R&D comprised only about 11 per cent of intangibles, roughly the same as software and databases, but far less than the $66 billion investment in "organizational capital." Policy analysis for innovation should give much greater emphasis than is now the case to the rapidly growing investment in intangible capital and to measurement of its contribution to productivity growth (Baldwin *et al.*, 2012).

Exhibit 3.6

Business R&D and Related Indicators for Canada, Major R&D Performing Industries

Industry	MAGNITUDE & INTENSITY				IMPACT		TRENDS		
	R&D Share (2012) (>4%)	GDP Share (2012) (>1%)	R&D Intensity (2012) (>3%)	Patent Share (2003–2010) (>3%)	Patent ARC (>1.0)	Pub. ARC (>1.0)	R&D Growth (2001–2012) (>4%)	GDP Growth (1997–2008) (>5%)	Export Growth (1997–2008) (>5%)
Scientific research and development services*	11.17	0.34	32.78	3.39	0.54	1.60	15.42	7.71	6.42
Communications equipment manufacturing**	9.87	0.14	70.04	23.98	2.03	1.84	-4.75	-0.25	-0.85
Wholesale trade	8.40	5.39	1.55	3.32	0.88	1.33	5.37	4.97	5.24
Aerospace products and parts manufacturing	8.38	0.42	20.02	3.83	0.90	1.04	4.63	3.76	6.50
Computer systems design and related services*	8.23	1.17	7.02	4.88	1.69	1.08	4.76	7.71	6.42
Information and cultural industries	8.16	3.31	2.46	24.52	2.09	1.55	15.98	5.49	4.13
Oil and gas extraction, contract drilling and related services	4.17	5.79	0.72	0.45	2.86	0.68	15.53	14.60	15.38
Pharmaceutical and medicine manufacturing	4.15	0.30	13.80	3.34	0.95	1.65	-0.38	5.80	13.85
Machinery manufacturing	3.81	0.96	3.97	6.61	0.97	0.84	3.36	2.75	3.84
Semiconductor and other electronic component manufacturing**	3.09	0.10	31.00	2.05	1.67	1.83	-3.01	-0.25	-0.85
Navigational, measuring, medical and control instrument manufacturing**	2.42			4.88	1.05	1.07	0.66	-0.25	-0.85
Architectural, engineering and related services*	2.28	1.19	1.91	0.94	0.89	0.88	-0.81	7.71	6.42
Petroleum and coal products manufacturing	2.12	0.46	4.39	0.11		0.47	13.72	11.23	13.97
Motor vehicle and parts	2.05	1.02	1.98	3.50	1.08	0.99	-0.99	-2.76	-1.46
Other chemicals	1.83	0.49	1.13	2.95	0.98	1.30	3.15	-1.37	3.90
Finance, insurance and real estate	1.61	18.95	0.08	1.57	2.44	0.79	6.45	4.63	4.62
Other manufacturing industries	1.50			1.24	1.34	0.87	4.51	4.75	-1.39
Fabricated metal product manufacturing	1.39	0.87	1.61	0.82	0.54	0.44	7.86	4.02	3.08
Electrical power generation, transmission and distribution	1.17	1.97	0.05	0.00		0.60	-1.50	2.55	8.23
Electrical equipment, appliance and component manufacturing	1.08	0.26	0.34	4.65	1.00	1.5	-3.10	1.01	2.97
Primary metal (non-ferrous)	1.05	0.83	0.37	0.81	0.27	1.15	-0.47	3.72	6.88

The table includes indicators of technology strength for 17 industries that account for more than 80 per cent of Canada's business R&D and 90 per cent of patents. Shaded cells highlight relatively strong performance. (See Box 3.2 for observations on the assignment of BERD to certain industries.) *Data for GDP and export growth for architectural, engineering, and related services; computer system design and related services; and scientific research and development services are based on aggregated data from Statistics Canada for "professional, scientific, and technical services." **Data for GDP and export growth for communications equipment manufacturing; navigational, measuring, medical and control instrument manufacturing; and semiconductor and other electronic component manufacturing are based on aggregated data from Statistics Canada for "electronic product manufacturing." Data are for selected industries. Calculations are explained in CCA (2013a).

Data source: CCA (2013a), Table 6.1

complementary perspectives. Both begin from the viewpoint of individual firms, recognizing that these are the economic agents that translate ideas into the innovations that, in aggregate, ultimately drive productivity.

The *Innovation Impacts* report positions the firm within an innovation ecosystem (see Box 3.3) characterized by the following aggregate behaviours:

- **Market demand conditions** — A deep understanding of customer needs, wants, and behaviour, combined with the heat of competition, is the primary motivator of firm-level innovation. Demand conditions in the Canadian market do not always stimulate innovation since domestic competition is mitigated by (i) regulation in certain industries, e.g., foreign ownership restrictions, marketing boards, various provincial and interprovincial restrictions; and (ii) the small and fragmented nature of the domestic market, which makes it less attractive to potential foreign competitors.

- **Knowledge generation** — Innovation originates with ideas, and thus universities are essential components of the ecosystem. They are not primarily a direct source of ideas,[14] but rather the training ground to equip people with the skills to innovate and apply the best ideas from around the world, as well as to manage the innovation process itself.
- **Innovation facilitation** — The facilitating elements of the ecosystem (which often also generate and convey knowledge) include, for example, angel and venture capital investors/mentors, government labs and extension services like the Industrial Research Assistance Program (IRAP), innovation incubators, and a vast array of technical and management consultants. The facilitating activities constitute essential "connective tissue" needed to bridge the gap between university knowledge generation and its commercial application. Often these are most effective when grouped together in clusters (e.g., Silicon Valley, the Waterloo area).
- **Policy-making** — Interventions are usually required to sustain and improve the performance of the ecosystem when market forces alone fail t o produce the best outcomes. For example, competition generally needs to be encouraged since too much market power usually blunts the motivation to innovate; regulation may be required to stimulate innovation to achieve aspirational goals that firms cannot pursue alone (e.g., fuel efficiency and emission standards, carbon pricing); R&D subsidies may be justified when the anticipated public benefit exceeds the private return; and targeted government procurement can be very effective in stimulating the growth of innovative firms, especially in the early stages.

14 A representative survey of more than 1,000 R&D-performing Canadian firms, undertaken for *Innovation Canada: A Call to Action* (the "Jenkins report"), found that employees, customers, and other businesses and competitors were by far the most important sources of innovation ideas; whereas post-secondary institutions were among the least mentioned (Industry Canada, 2011).

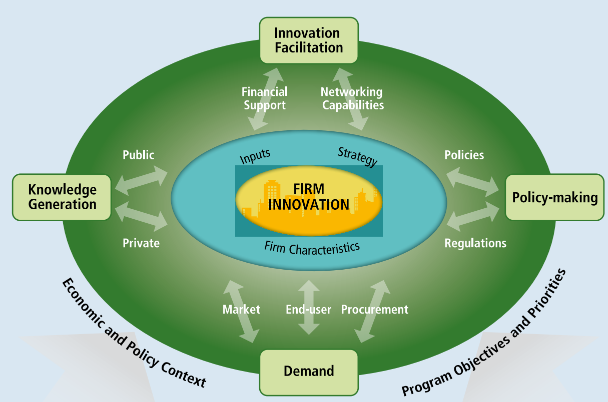
BOX 3.3 The Firm-Centric Innovation Ecosystem

In 1841 German economist Friedrich List suggested that the growth of a national economy depended on the linkages and flows of knowledge between economic actors. This was a novel insight at the time. Today, we understand more clearly that an ecosystem metaphor is more appropriate than conceptualizing innovation as a linear process from investment to impact. It captures the fundamental nature of innovation: a non-linear and dynamic process, rooted in an intricate set of activities and linkages among actors in the system.

An innovation ecosystem provides resources for the central agent of innovation — the firm. Yet, as the innovation ecosystem approach emphasizes, firms do not operate in isolation; rather, they exploit the vital resources that flow from the interactions between ecosystem actors. An innovation ecosystem provides the knowledge, the capital (physical, financial, and social), the policy and regulatory conditions, and market demand that sustain business innovation. By analyzing the health of the innovation ecosystem, it is possible to pinpoint bottlenecks that hinder innovation, and to identify leverage points to drive innovation. This suggests a much larger and richer set of innovation investments to be considered and potentially leveraged by policy-makers.

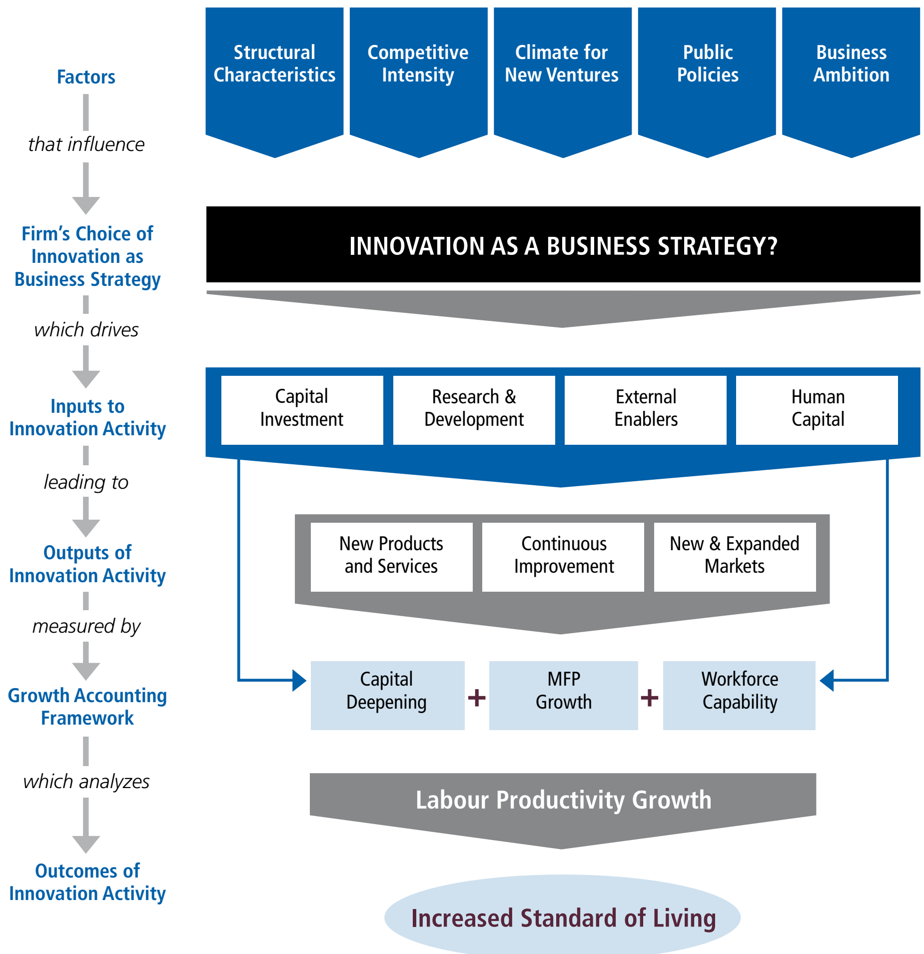
Two premises provide a framework for assessing the impact of innovation investments: (i) aggregate behaviours as the determinants of ecosystem health, and (ii) firms as the central innovation agents. The firm-centric innovation ecosystem approach encompasses the five most salient aggregate behaviours of the ecosystem, as illustrated below.

The Firm-centric Innovation Ecosystem



Data source: CCA (2013b)

Exhibit 3.7
Logic Map of the Business Innovation Process



Data source: CCA (2009), Figure 4.2

The *Innovation and Business Strategy* (2009) report is complementary to the ecosystem perspective. It explores in depth the factors that influence a firm's decision whether or not to make innovation a core element of its business strategy (see Exhibit 3.7 and Exhibit 3.8 for examples of the main types of innovation strategies employed under different market conditions). A focus on innovation inputs like academic research, highly qualified people, and R&D puts the cart before the horse. The firm must first decide that a commitment to innovation, and the investments required, makes business sense.

With the implicit understanding that the needs of a firm's customers overlay the five factors at the top of Exhibit 3.7, there is considerable commonality between the ecosystem elements outlined above and the determinants of business strategy in Exhibit 3.7.[15] Since these factors operate, in one form or another, in all countries, the fundamental question remains as to why, in Canada's case, they have not led to more innovation-focused business strategies.

There appear to be three principal reasons:

- **Canada's role in an integrated North American economy** — By virtue of an exceptional resource endowment and adjacency to the world's most dynamic and innovative economy, Canada's comparative advantage has for generations been as an upstream supplier of both commodities and cost-competitive manufactured products in highly integrated value networks largely dominated by U.S. firms. These conditions far predate

15 The "structural characteristics" element may need explanation. It refers to particular features of the firm's industry, e.g., is it in an industry where low-cost production of standard items is the dominant competitive factor, or is the business foreign-controlled with responsibility for innovation vested in its head office? In such cases, which are common in Canada, an innovation-based strategy may be neither necessary nor feasible.

the North American Free Trade Agreement (NAFTA), and have been supported by policies such as the Auto Pact and others that tolerated, or even encouraged, export of raw or lightly processed resources ("rip and ship"). Many Canadian firms have excelled in the kind of "plant floor" innovation that keeps cost down and quality up (e.g., auto assembly). But few, despite notable exceptions, have specialized at the leading edge of technology (i.e., the kinds of activities that produce high BERD intensity and require lots of people with advanced degrees in science and engineering). Acquiring needed innovation from the United States has simply been easier and cheaper.

- **Size of the domestic market** — Small markets tend to support less innovation than large markets because the smaller reward potential often does not justify the cost and risk of innovating. This has been exacerbated in Canada's case by the extraordinary competitive power of the United States, whose market Canadian firms have had trouble penetrating at the consumer level — a level where innovative business strategies are usually essential. Meanwhile, a concern over potential U.S. domination of certain industries in Canada, notably communications, transport, and agriculture, has led to protective policies that have reduced competition with the unintended effect of reducing the motivation to innovate. The examples of small innovative powerhouses like Switzerland and Sweden, among many others, prove that a small domestic market does not necessarily inhibit innovation. The key is that these countries are aggressive competitors in global markets — as they *had* to be. Many Canadian exporters, however, have been content with the U.S. market right next door and to play an upstream or subsidiary role, as described in the first factor above.
- **Commercial success of Canadian business** — Most significantly, Canadian business has prospered in its chosen niche. Aggregate profitability ratios have matched or exceeded those in the United States. With little motivation to change a successful formula, many firms have settled into a "low-innovation equilibrium" that has conditioned business habits and ambitions, and shaped the predominant business culture in Canada.[16] Canadian business behaviour cannot, therefore, be expected to change unless the conditions that have sustained its profitable, low-innovation equilibrium change first (see Box 3.4).

As the next chapter concludes, those changes are already well underway.

BOX 3.4 *Wanted: Small Catastrophes*[17]

"Canada's problem is that technology and innovation from parent corporations, but also from other easily accessible foreign sources, have been so readily available, so economically attractive in the short term, that the growth of systematic, broad-based, indigenous innovative and technological capability has been severely inhibited […]

The lack of need to make risk decisions in Canada and the consequent stunting of experience in making such decisions have conditioned the managers of manufacturing enterprises in Canada into becoming inexperienced, diffident and reluctant risk-takers […] We lack, above all, the entrepreneurial initiative achieved by others, not because their people have greater potential than Canadians, but because their corporations and their countries have been forced to develop more vigorous responses by exposure to severe conditions from which we have been insulated […]

The generation of indigenous technology, and the relentless search for expanding markets, did not come about in Sweden and similar countries, or even in Northern Electric, because our government provided incentives for appropriate behaviour. They developed as natural and instinctive survival responses to demands from the environment.

[…] It is uncertain whether any incentive plan to stimulate the growth of domestic technology and innovation, or to make corporations expand aggressively into foreign markets, can achieve significant success when it is applied to companies in which the drive to do these things has not already been forced to emerge because of exposure to a real stimulus from the economic environment. What we seem to need in Canada are 'small catastrophes'."

16 One internationally experienced member of the Expert Panel on Business Innovation put it succinctly: "Most Canadian businessmen would rather behave like an income trust than like a venture capitalist!"

17 Excerpt from Marquez (1972). Mr. Marquez was, at the time, CEO of Northern Electric, later to become Nortel Inc. His views, based on practical experience on the front lines of the technology industry, and having experienced the "catastrophe" of losing privileged access to Bell Labs' technology when AT&T's monopoly was broken up, give a particularly vivid account of the factors that have shaped, and continue to shape, the innovation behaviour of Canadian business.

Exhibit 3.8

The Six Games of Innovation

	Autonomous products	Closed Systems	Platform-Based Products
EMERGING MARKETS New offerings — sometimes radically innovative, generating emulation and intense competition R&D-intensive — typically 20% to 35% of sales Encountered in roughly 10% of the economy but contributing approximately 30% to 35% of GDP growth	**Eureka!**	**System Breakthrough**	**Battle of Architecture**
	A new stand-alone product — e.g., the telephone; a block-buster drug	A major system component — e.g., SAP, jet engine, MS-DOS	A new system takes hold — e.g., the QWERTY keyboard, Windows, Google, iPhone — creating a "platform" to which many modules ("apps") can attach
	Usually S&T-based, but not exclusively (e.g., Cirque du Soleil)	Often emerge from collaboration between an inventor (e.g., Bill Gates) and a demanding client (e.g., IBM)	Success depends on coalition-building and network (lock-in) effects, leading to rapid concentration
	Intense competition generates rapid improvement	Managing the customer (partner) relationship is a key challenge	Venture capital often key in early funding of visionaries
	Focus on market development and managing rapid growth		
	Consolidation as winners emerge		
	Accounts for about 15% of GDP growth	Accounts for about 5% of growth	Accounts for about 15% of growth
MATURE MARKETS Improved value through incremental innovation in products and processes Moderate R&D intensity — roughly 3% to 6% of sales Encountered in roughly 90% of the economy and contributing approximately 65% to 70% of growth.	**New and Improved**	**Pushing the Envelope**	**Mass Customization**
	Continuous improvement of products and processes. Frequently found in manufacturing for consumer markets — e.g., P&G and 3M are classic exponents	Market consists of very large clients seeking continuously to improve their offering and systems, working with experts and suppliers — e.g., governments, banks, airlines, utilities, civil infrastructure	Battle of brands through innovation in systems and their elements — e.g., Wal-Mart, IKEA, Toyota, Google, Amazon
	Focus on constant incremental (systematic) innovation to lower cost and differentiate offerings	Technological innovation *per se* is not the focus — improved application is	Depends on continuous improvement of both platform and product
		Project management is a critical success factor	Requires management of (global) networks of trusted suppliers
	Accounts for about 30% of growth	Accounts for about 15% of growth	Accounts for about 20% of growth

Data source: CCA (2009), Table 1; Miller & Côté (2012)

4

Looking Forward

Four megatrends appear destined to shape the competitive environment facing Canadian business, and the policy challenges for governments, for years to come.

First, declining growth rates in the United States and other highly developed economies, combined with a shift in economic weight and competitive vitality to emerging markets, especially in Asia, are shifting the locus of export opportunity (and import competition) from areas where Canada has enjoyed a unique geographical and cultural advantage. Despite an export-heavy economy, Canada has been less a trading nation than a junior partner in a set of highly integrated North American value networks. Major adjustments will be required in the attitudes and strategies of Canadian business.

Second, the global demand for resource commodities, particularly energy, will almost certainly remain strong, oscillating around an upward, development-driven trend. This is already creating growing environmental challenges and volatile price swings. These destabilizing factors will drive worldwide research priorities aimed at developing new sources and/or substitutes, adding to the uncertainty. Canada's economy will be at the epicentre of these developments, challenging Canadian resource firms to become innovation leaders.

Third, S&T revolutions in ICT, and fields like genomics and nanotechnology, are still in their formative stages and destined to invade all aspects of business and social life. ICT is accelerating the pace of economic change and will continue to overturn business models (including, for example, the delivery of post-secondary education). To remain competitive, Canadian firms will have to be among the leaders in the innovative application of ICT and other enabling technologies. They are not there now.

Finally, population ageing, by reducing the share of the population that is of working age, will pull in the opposite direction from the labour-reducing effect of ICT. The demographic trend will tend to create worker shortages, thus placing a premium on productivity growth and the innovation required to create it. Because of the long lead times in building human capital, anticipatory action is needed.

These megatrends have changed the game. Canadian business is, for the most part, ill prepared to play, accustomed as it has been to more than a century of profitable, secure, and relatively comfortable integration with the United States. Many Canadian firms operating at the cutting edge of global competition are already keenly aware of the challenges and opportunities ahead. Others have an intellectual awareness, but not yet the visceral realization that is needed to motivate a meaningful change in strategy. But it is coming — fast.

Looking to the future, Canada's fundamental challenge is to transform its commodity-based economy to one based on providing a greatly expanded number of markets with an increased variety of goods and services where firms must compete primarily on the basis of product and marketing innovations rather than simply on low costs of standard production. And, as more Canadian firms, out of sheer necessity, develop strategies that focus on innovation, they will create a much more powerful "business-pull" on Canada's strong S&T capacity. That is why governments must continue to provide the support needed to sustain Canada's research excellence as the demand for leading-edge skills and ideas rises to meet the supply.

The principal objectives of innovation policy, in this new context, are to:

- create or amplify the market signals that will encourage firms to adopt innovation-based strategies, e.g., market framework and procurement policies; and
- improve the capacity of the innovation ecosystem to support firm-level innovation primarily by aligning and strengthening the connecting links among institutions, policy domains, and jurisdictions.

BOX 4.1 Council Contributions to Understanding S&T and Innovation in Canada

The Council of Canadian Academies does not undertake original research, other than occasionally through surveys and the novel analysis of data. The principal value contributed by the Council's assessments of S&T and innovation arises from the communication to a broad audience, including senior policy-makers, of research and other technical work assessed and synthesized by multidisciplinary expert panels that scrupulously acknowledge the primary sources. In that spirit, the Council's notable contributions to a broader and deeper understanding of S&T and innovation in Canada include the following:

- assessment of S&T strengths (along several dimensions) in a broad array of disciplines based on leading-edge bibliometrics and original surveys of international and domestic experts;
- quantitative linkage of Canada's poor productivity growth with weak business innovation, through emphasis on MFP as the best indicator of innovation in the application of technology, managerial efficiency, and industrial organization;
- sector-based accounting for Canada's business R&D performance, including the factors (structure/intensity) responsible for the persistent gap relative to the United States, and the sharp decline in Canadian R&D intensity since 2001;
- emphasis on Canada's exceptionally weak business investment in ICT (particularly relative to the United States) and its implications for innovation and productivity growth, including a proposal that was later reflected in the government's Digital Technology Adoption Pilot Program (DTAPP);
- an historical perspective on the factors that have profoundly influenced Canadian business behaviour in the context of innovation; and
- proposal of a broader conception of business innovation, noting the inherent limitations of a focus on R&D and describing a new firm-centric paradigm that emphasizes the innovation ecosystem and key factors that influence a firm's choice of innovation as a core business strategy.

The Council's work, summarized in this document, suggests that the conceptual framework governing innovation policy needs to shift from the prevailing paradigm of R&D *supply-push* to a *demand-pull* perspective centred on the firm, the innovation ecosystem, and the factors that determine the choice of business strategy.

In summary:

- Policy-makers and commentators need to acknowledge that the business innovation problem in Canada has a pedigree as old as the country itself.
- Canadian business has not become more innovative because it has been able to prosper without needing to do so.
- Now, because circumstances are becoming radically different from those that have shaped Canadian business culture and strategic behaviour for more than a century, business will have to embrace innovation-focused business strategies to compete and survive.
- This creates the conditions where public policies to support business innovation can be more effective than in the past because innovation policy objectives and business motivation will finally be aligned.

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