The State of Industrial R&D in Canada

Executive Summary

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

THE STATE OF INDUSTRIAL R&D IN CANADA

The Expert Panel on the State of Industrial R&D in Canada

THE COUNCIL OF CANADIAN ACADEMIES
180 Elgin Street, Suite 1401, Ottawa, ON, Canada K2P 2K3

Library and Archives Canada Cataloguing in Publication
The state of industrial R&D in Canada / The Expert Panel on the State of Industrial R&D in Canada.

Issued also in French under title: L'état de la R-D industrielle au Canada.

Includes bibliographical references.

Issued in print and electronic formats.

ISBN 978-1-926558-59-2 (bound).--ISBN 978-1-926558-60-8 (pdf)

1. Research, Industrial–Canada. 2. Technological innovations–Canada.
I. Council of Canadian Academies. Expert Panel on the State of Industrial R&D in Canada, author II. Title: State of industrial research and development in Canada.

T177.C2S73 2013 607'.271 C2013-904302-0

This report should be cited as:
Council of Canadian Academies, 2013. *The State of Industrial R&D in Canada*. Ottawa, ON: The Expert Panel on Industrial R&D in Canada, Council of Canadian Academies.

Printed in Ottawa, Canada

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Canada This assessment was made possible with the support of the Government of Canada.

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Science Advice in the Public Interest

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Expert Panel on the State of Industrial R&D in Canada

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Message from the Chair

Over the past several decades, both employment and economic growth in Canada have been strong. In fact, Canadians enjoy one of the highest standards of living in the world. Our post-secondary education sector is world leading, both in terms of scientific contributions and well-trained graduates. However, just below the surface of this economic and social prosperity lie some troubling trends. Canadian GDP per capita remains roughly only 80 per cent of the U.S. level, Canadian labour productivity growth lags behind that of the United States and many other countries, and Canadian innovation is generally deemed sub-par.

Since industrial research and development (IR&D) is an important contributor to the innovation process, it is not surprising that it has been a source of perennial concern for Canadian policy-makers. This concern led to the formation of the Expert Panel on the State of Industrial R&D in Canada. The Panel examined the best available data and academic literature to assess the state of IR&D in Canada. Over many deliberations, the Panel struggled both with data limitations and the challenge of understanding the complex relationships between IR&D and other indicators of academic research, innovation, productivity, and standard of living. It is here where I think the Panel's work is most important and interesting, yet also the most incomplete. We have identified key areas for further study, which we hope will be taken up by others. While this assessment has been challenging, I am confident the final report clearly assesses the state of IR&D in Canada, and will serve as an important baseline for evaluations and decisions going forward.

On behalf of my colleagues on the Expert Panel, I would like to thank the reviewers who took the time to critique this report to ensure it was balanced and evidence-based, featuring useful analysis for its Sponsor.

Finally, the Panel and I could not have produced a report of this calibre without the assistance and intellectual contributions of Council staff under the expert guidance of its President, Elizabeth Dowdeswell.

Kathleen Sendall, C.M., FCAE
Chair, Expert Panel on the State of Industrial R&D in Canada

Acknowledgements

Over the course of its deliberations, the Panel sought assistance from many individuals and organizations that provided valuable evidence and information for consideration. Special thanks go to the following: Ian Currie, consultant and researcher; Greg Peterson, Louise Earl, and Ziad Ghanem of Statistics Canada; Eric Archambault, Grégoire Côté, and colleagues at Science-Metrix; Janice C. Simpson of Redoaks Management Consulting Inc.; Peter Jarrett and Alexandra Bibbee of the OECD; and Professor Bev Dahlby of the University of Alberta.

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Report Review

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

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

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

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The report review procedure was monitored on behalf of the Council's Board of Governors and Scientific Advisory Committee by **Dr. Tom Brzustowski, O.C., FRSC, FCAE,** Chair of the Board of the Institute of Quantum Computing at the University of Waterloo. The role of the report review monitor is to ensure that the panel gives full and fair consideration to the submissions of the report reviewers. The Board of the Council authorizes public release of an expert panel report only after the report review monitor confirms that the Council's report review requirements have been satisfied. The Council thanks Dr. Brzustowski for his diligent contribution as review monitor.

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

Executive Summary

Industrial R&D (IR&D) is the private sector's investment of time and resources in the development of new ideas, technologies, and processes to promote business performance and create better products. IR&D also contributes to meeting pressing social challenges, ranging from development of new medical treatments to mitigation of environmental impacts to changing the ways in which Canadians work together. The returns on investments in IR&D can be high for the firms undertaking it, the economy at large, and, in particular, the region in which the IR&D takes place.

IR&D and innovation are not synonymous. IR&D consists of any scientific research or technology development undertaken by Canadian businesses. Innovation, on the other hand, is a broader concept that can be defined as "new or better ways of doing valued things." IR&D is a critical driver of innovation, which, in turn, plays an important role in catalyzing productivity gains across the economy, thereby stimulating wealth creation and improving living standards for all Canadians. The historically low rate of investment in IR&D in Canada compared to other countries is one of the key factors that also accounts for the consistently wide gap in productivity growth between Canada and the United States.

CHARGE TO THE PANEL

For most of the 20th century, and now into the 21st, Canadian policy-makers have attempted to craft policies to better promote IR&D and innovation in Canada. Understanding the current state of IR&D is critical to effective policy development. In 2011 the Minister of Industry, on behalf of Industry Canada, asked the Council of Canadian Academies (the Council) to respond to the following charge:

> *What is the current state of industrial research and development (IR&D) in Canada?*
>
> - *What are Canada's industrial R&D strengths? How are these strengths distributed by sector and geographically across the country? How do these trends compare with what has been taking place in comparable countries?*
> - *In which scientific disciplines and technological applications are our relative strengths most aligned with Canada's economic strengths/industry needs?*
> - *What are the key barriers and knowledge gaps in translating Canadian strengths in S&T into innovation and wealth creation?*

The Council assembled a panel of 14 leading experts (the Panel) with a diverse range of professional and academic expertise. The Panel's focus was R&D undertaken by, or at the direction of, Canadian businesses (i.e., IR&D). This assessment complements the Council's 2012 assessment of Canada's S&T strengths, primarily as embodied in the research efforts in Canada's higher education sector and in government.

ASSESSING THE STATE OF IR&D IN CANADA

Assessing the state of IR&D in Canada is a complex undertaking. The Panel examined measures of IR&D inputs (expenditures and personnel), outputs (patents and scientific publications), and outcomes (rates of innovation and other economic outcomes). The Panel's detailed analysis of patenting and scientific publication patterns at the industry level is the first of its kind in Canada. In addition, the Panel identified and assessed Canada's IR&D strengths based on selected measures of magnitude and intensity, impact and quality, and trends.

THE STATE OF IR&D IN CANADA

The Canadian business sector invests relatively little in IR&D compared to peers abroad, although some industries are highly IR&D intensive by international standards. The first part of this finding is consistent with previously published studies, and continues to be troubling given Canada's persistent record of relatively low productivity growth. Most significantly, the low level of IR&D investment suggests that IR&D is not the principal strategy followed by many Canadian firms in maintaining their competitiveness. Expressed as a share of GDP, IR&D expenditures in Canada are now roughly half the U.S. level and declining. Several Canadian industries, however, show higher IR&D intensities than those of other G7 countries. These include communications equipment manufacturing, office and computing machinery manufacturing, coke and refined petroleum products manufacturing, and pulp and paper.

The IR&D intensity gap between Canada and the United States is largely driven by Canada's low IR&D intensity in the manufacturing sector. The relatively large share of the Canadian economy accounted for by natural resource industries has almost no impact on this gap. Instead, some of Canada's high-technology manufacturing industries, such as semiconductor and computer equipment manufacturing, form a smaller share of the economy in Canada than in the United States. This smaller size drags down the manufacturing sector's aggregate IR&D intensity. The declining share of these high-technology manufacturing industries in the Canadian economy in recent years has further

exacerbated this effect. While a relatively high degree of foreign ownership may act to lower IR&D in some industries, such as motor vehicle manufacturing, it is unlikely that this fully explains the overall picture in Canada.

Many industries that traditionally do not spend as much on IR&D have either increased or maintained their IR&D expenditures and intensity in recent years in Canada. Some of these industries reflect Canada's traditional comparative advantage in natural resources, such as oil and gas extraction and pulp and paper manufacturing. The dominant source of competitive advantage for these industries is not development of new technologies. Rather, it comes from the rapid adoption of new ideas and technologies, which is facilitated by IR&D investment in these industries.

IR&D in Canada is relatively personnel intensive and less capital intensive when compared to other countries. Although Canada's rank by IR&D intensity is low among OECD countries, the share of the population employed in IR&D places Canada in the middle of the pack. Implicitly, the labour costs of Canadian IR&D personnel are low in comparison to other countries. Expenditures on capital equipment to perform IR&D are also proportionately lower. The full implication of these findings is unclear and warrants further study.

Fewer large firms undertake IR&D in Canada than in highly IR&D-intensive countries. The average size of firms performing IR&D in Canada is smaller than in other countries, and the share of total IR&D performed by smaller firms has increased. The relationship between IR&D expenditures and firm size is complex: IR&D intensity tends to be lower in larger firms, but larger firms are more likely to perform IR&D. Although it may be encouraging that smaller firms are undertaking relatively more IR&D, this could be holding back Canada's overall IR&D performance. There are economies of scale in IR&D, and larger firms may be needed to take the successes of smaller firms to a broader market.

Canada has the 12th highest rate of patents granted in the world, and the impact of Canadian patents is relatively high. Canada is responsible for 1.1 per cent of patents filed in Europe, Japan, and the United States, and around 4 per cent of the world's scientific journal articles. Canada also accounts for a relatively large share of world patents in pharmaceuticals and medicines (drugs), and communications technologies. Canadian industry patents are cited in other patents about 20 per cent more than the world average, suggesting a relatively high impact on development of related technologies.

Canadian firms report relatively high levels of innovation compared to firms in other countries. According to a series of innovation surveys in Canada and abroad, Canadian firms repeatedly report relatively high levels of innovation in contrast to their relatively low expenditures on IR&D. This suggests that Canadian firms do not rely on IR&D to generate innovation as much as firms in other countries. Innovation comes from other sources such as organizational change. It is less clear that Canadian firms perform as well in translating innovation into additional sales.

CANADA'S IR&D STRENGTHS

The Panel identified four industries of IR&D strength:

- Aerospace products and parts manufacturing
- Information and communication technologies (ICT)
- Oil and gas extraction
- Pharmaceutical and medicine manufacturing

These industries demonstrate strength by multiple measures, including those of magnitude and intensity, quality and impact, and trends. They all account for a substantial share of total Canadian IR&D, and have high levels of impact on at least one of the key IR&D outputs (patents or publications). There are, however, important differences both within and across these industries. Not all ICT industries show similar patterns of strength. Some, such as computer systems design and related services, show strength across nearly all measures. Others, such as communications equipment manufacturing, have high levels of impact on patents and publications, but have experienced declining IR&D expenditures and economic output in recent years. The aerospace industry accounts for a large share of world aerospace exports; however, the impact of its IR&D, based on patent and publication citations, is only average. The oil and gas industry has a high level of impact based on patent citations and rapid growth in both IR&D expenditures and economic output. While the pharmaceutical industry also shows strength by several measures of magnitude and impact, its IR&D expenditures have declined over the past decade.

The resulting picture of IR&D activity in Canada is complex and multifaceted, underlining the inherent multidimensionality of the concept of IR&D strength.

REGIONAL DISTRIBUTION OF IR&D ACTIVITY AND STRENGTH

Firms locating their IR&D facilities in close proximity can be a powerful driver of IR&D as neighbouring firms learn from and compete with each other. To assess the regional distribution of IR&D strengths in Canada, the Panel examined the provincial distribution of IR&D strength and activity. Based on these data, IR&D activities across all industries tend to concentrate in Ontario and Quebec. Across the four industries of IR&D strength identified by the Panel, these two provinces accounted for roughly three-quarters of total IR&D expenditures. Nonetheless, the distribution of IR&D activity in these industries varies considerably:

- *Aerospace*: Around three-quarters of all IR&D takes place in Quebec, and most of the remainder in Ontario.
- *ICT*: IR&D for almost all industries is most heavily concentrated in Ontario, with Quebec accounting for the highest share of computer and electronic product manufacturing. British Columbia also has a relatively high share of IR&D, particularly in computer and peripheral manufacturing, semiconductors, and computer system design and related services.
- *Oil and gas*: The regional distribution of IR&D is unclear due in part to data suppression to protect firm anonymity. The distribution of patenting activity, however, shows that the majority of IR&D most likely occurs in Alberta, with a substantial share in British Columbia.
- *Pharmaceuticals*: IR&D activities are distributed mainly across Ontario and Quebec, with British Columbia accounting for most of the remainder.

ALIGNMENT OF IR&D WITH CANADA'S S&T AND ECONOMIC STRENGTHS

The Panel found limited alignment between Canada's areas of science and technology (S&T) strength, IR&D strength, and overall economic strength. The Panel used the six research fields identified in the Council's 2012 State of S&T in Canada report as areas of S&T strength. The Panel then explored three measures that best capture economic strength at the aggregate level: industry growth, industry domestic size, and OECD relative size.

Figure 1 presents Canada's S&T strengths, IR&D strengths, and the industries that account for relatively large shares of the Canadian economy. There are some areas of congruence. Canada's research strength related to clinical medicine may be a contributor to the strength of the pharmaceutical and medicine manufacturing industry. Likewise, Canada's research strength in ICT is likely related to IR&D in the ICT sector. Canada's IR&D strengths related to the aerospace and oil and gas industries also directly map to areas where the Canadian economy shows a

relatively high level of specialization (i.e., aircraft and spacecraft manufacturing and mining and quarrying, which in this case includes oil and gas). These relationships are plausible and suggest connections are being made between Canada's S&T strengths, IR&D activities, and industries of particular economic importance to Canada. More research, however, is required to further validate, document, and explore these relationships.

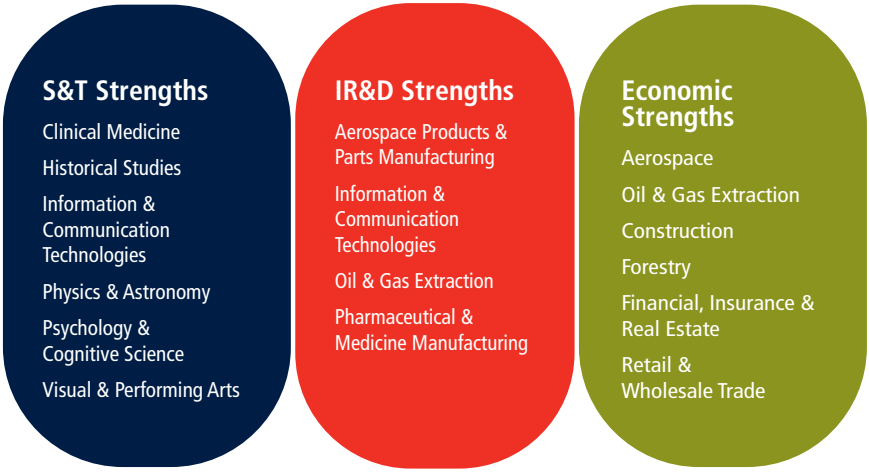

Figure 1
Alignment of Canadian S&T, IR&D, and Economic Strengths

A limited congruence between S&T, IR&D, and economic strengths is in part to be expected because of the inherently complex, dynamic, and non-linear nature of these relationships, and the different incentives for production of knowledge in different spheres. These interactions take place within a system in which all the drivers must be strong.

One of the critical components of an effective system is strong demand for innovative products. Not only must there be a plentiful supply of skilled workers and ideas from higher education, but demand for these critical inputs must also be strong. It is often suggested that insufficient competitive intensity in the Canadian economy limits demand for innovation, and in turn for IR&D. Firms invest less in IR&D without the imperative to develop new products and lower costs to survive and prosper, or to use new technologies to improve their competitiveness.

The Panel also identified five barriers to translation of S&T knowledge into innovation and wealth creation advanced by the academic and public policy literature:

- *Technology transfer*: Low rates of growth in patents and licensing agreements at Canadian higher education institutions, relative to new investments in research and technology transfer personnel, suggest existing technology transfer processes are not effective.
- *Managerial expertise*: Evidence suggests that Canadian managers have lower levels of education than their counterparts in the United States; and that managerial, commercialization, and organizational skills may be partially responsible for Canada's record of comparatively low productivity growth.
- *Business support*: New ventures in Canada receive relatively little direct public funding support for development and commercialization of new technologies. Unlike other countries, the majority of public support for IR&D in Canada is provided through tax credits, rather than direct investment.
- *Public procurement*: Relatively few demand-side policies in Canada encourage IR&D by creating markets for new technologies, products, or services.
- *Business culture*: Canadian business leaders are risk averse relative to their U.S. counterparts. As a result, Canadian firms may be less likely to take on the risks associated with translating new research discoveries into commercial products and/or using new technologies.

CHALLENGES OF IR&D DATA AND INDUSTRY CLASSIFICATION PRACTICES

The Panel encountered significant challenges in the way that data on IR&D expenditures (and other variables) are assigned to specific industries in Canada. IR&D expenditures are currently assigned according to the principal activity of an industry rather than to the industries served by the IR&D. Although conforming to the OECD's *Frascati Manual*, this practice made it difficult for the Panel to obtain the desired level of detail and precision in its assessment of the Canadian IR&D landscape.

The Panel questioned whether the available data underestimate the amount of IR&D undertaken in support of certain manufacturing industries. Since manufacturing increasingly takes place elsewhere in the world, IR&D is often assigned to the wholesale trade services industry because only marketing and IR&D activities remain in Canada. For example, IR&D aimed at developing new drugs may be assigned to the scientific research and development or wholesale trade industries, rather than to the pharmaceutical manufacturing industry.

Since 2004, the United States has adjusted its data manually to address this issue. This change has resulted in a large shift of IR&D expenditures out of wholesale trade and into highly IR&D-intensive industries such as pharmaceuticals and information and communication technologies. Some European statistical agencies also require that firms specify for which product(s) the IR&D is being conducted.

FINAL REFLECTIONS

When judged by many of the traditional indicators, Canada's overall IR&D performance is relatively weak. Canada, however, has substantial IR&D strength in several key industries. In addition, there may be many other niche areas of Canadian excellence and technological development. Nothing precludes Canadian researchers and businesses from making advances and contributions across all industries (or all scientific domains). A single, small firm can have a large impact on a globally dispersed industry with the introduction of the right technology at the right time.

Inevitably, the future commercial successes or failures in many industries will hinge on the extent to which Canadian firms are capable of adopting, developing, and marketing world-leading technologies. Building a strong foundation of IR&D is an essential part of developing that capacity for the future, thereby ensuring that Canadian firms can successfully compete in a global economy increasingly centred on knowledge and technology.