August 2013

Report in Focus

THE STATE OF INDUSTRIAL R&D IN CANADA

Industrial research and development (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 contributes to meeting pressing social challenges, ranging from developing new medical treatments to mitigating environmental impacts to changing the ways in which Canadians work together. In this sense, IR&D is often the key to unlocking the door to a set of products that revolutionize the very way in which we live our lives. The returns on investments in IR&D can be high for the firms undertaking it, the economy at large, and 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. This stimulates wealth creation and improves 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 account for the consistently wide gap in productivity growth between Canada and the United States.

CHARGE TO THE EXPERT 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?

In response, the Council assembled a panel of 14 leading experts (the Panel) with a diverse range of professional and academic expertise. The Panel was chaired by Kathleen E. Sendall, Director of CGG in Paris, France, and Director of Enmax Corporation in Calgary, Alberta. The Panel's focus was R&D undertaken by, or at the direction of, Canadian businesses (i.e., IR&D). The assessment, which complements the Council's 2012 assessment, *The State of Science and Technology in Canada*, is one of the most detailed and systematic studies of the state of industrial research and development ever undertaken in Canada.

Assessing the State of IR&D in Canada

IDENTIFYING AREAS OF IR&D STRENGTH

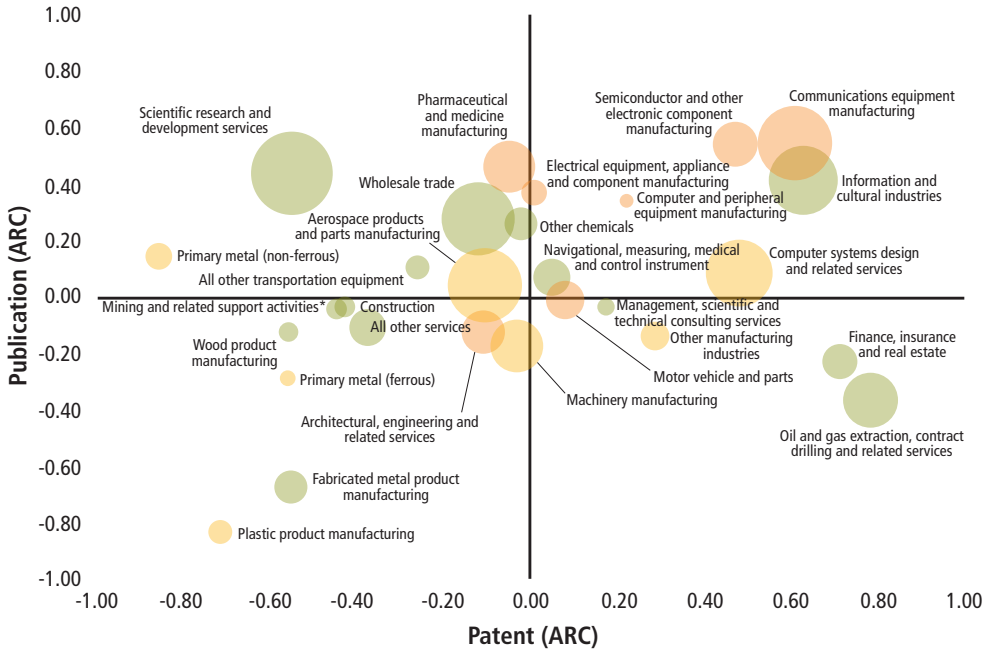
Assessing the state of IR&D in Canada is a complex undertaking. The Expert Panel examined measures of IR&D inputs (expenditures and personnel), outputs (patents and scientific publications), and outcomes (rates of innovation and other economic outcomes). The detailed analysis of the patenting and scientific publication patterns at the industry level is the first of its kind in Canada.

Taken together, these data provide a clear picture of Canada's IR&D strengths (see Figure 1 and Table 1). The results speak to the breadth and complexity of IR&D activity in Canada, and confirm that the concept of IR&D strength is inherently multifaceted, and cannot be captured or summarized by any single measure.

The following key industries of IR&D strength were identified:

- 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. There are, however, important differences both within and across these industries. For example, 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 its IR&D expenditures and economic output have declined 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.



*R&D Expenditure share for mining and related support activities is for 2011.

Data source: Statistics Canada (2012a); Science-Metrix tabulations based on data from Scopus (Elsevier) and the USPTO

Figure 1. Distribution of Patent and Publication Citations in Canada, 2003–2010

This figure shows an industry's share of total IR&D (size of bubble), average relative citations of patents (x-axis), and average relative citations of publications (y-axis). Industry bubbles are also coloured according to whether IR&D expenditures have increased (green), decreased (red), or remained stable (yellow). Average relative citation scores are presented here as the hyperbolic tangent of the natural logarithm to produce a symmetrical scale, with zero equivalent to the world average.

Industry	MAGNITUDE & INTENSITY				IMPACT		TRENDS		
	IR&D Share (2012) (>4%)	GDP Share (2012) (>1%)	IR&D Intensity (2012) (>3%)	Patent Share (2003–2010) (>3%)	Patent ARC (>1.0)	Pub. ARC (>1.0)	IR&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

Data source: Panel analysis based on Statistics Canada (2012a), and Science-Metrix calculations based on data from Scopus (Elsevier) and USPTO

Table 1. IR&D Indicators of Magnitude and Intensity, Impact, and Trends in Canada

The table shows summary indicators by industry for selected measures of magnitude and intensity, impact, and trends. Data are presented only for those industries that accounted for more than one per cent of total IR&D expenditures in 2012. Industries are listed in descending order by share of total IR&D. Shading indicates which industries satisfy the conditions stipulated under the variable headings across the second row from the top. IR&D expenditure and intensity data for the petroleum and coal products manufacturing industry is for 2010. IR&D intensity is expressed as a share of industry GDP. Patent share and patent average relative citation are based on patents filed at the USPTO between 2003 and 2010, as calculated by Science-Metrix. IR&D growth is the average annual growth rate in IR&D expenditures between 2001 and 2010. GDP growth and export growth are the compound annual growth rates between 1997 and 2008. *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".

REGIONAL DISTRIBUTION OF IR&D ACTIVITY AND STRENGTH

To assess the regional distribution of IR&D strengths in Canada, the Panel examined IR&D strength and activity by province. 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. Alberta and British Columbia also emerged as regions of strength. The leading provinces in each of the four industries are as follows:

- Aerospace: Quebec and Ontario
- ICT: Ontario, Quebec, and British Columbia
- Oil and gas: Alberta and British Columbia
- Pharmaceuticals: Ontario, Quebec, and British Columbia

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

The Panel also sought to understand how Canada's IR&D strengths align with Canada's areas of strength in science and technology (S&T) research and economic performance. Figure 2 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. For instance, 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 ICT industries. While 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, the Expert Panel concluded that this alignment is limited, and more research is required to further validate and explore these relationships.

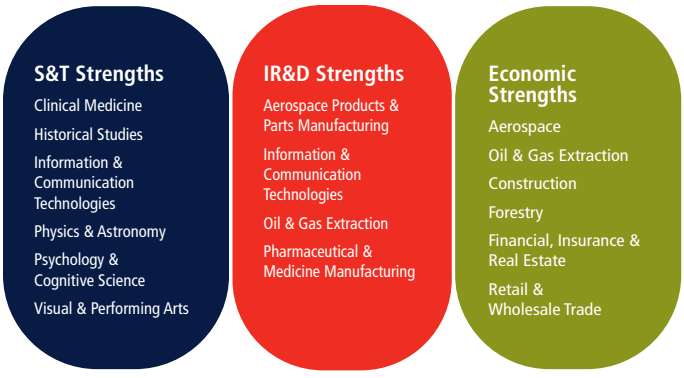


Figure 2. The Alignment of Canadian S&T, IR&D, and Economic Strengths

ADDITIONAL KEY FINDINGS

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.

The academic and public policy literature suggests five barriers to the translation of S&T knowledge into innovation and wealth creation.

- **Technology transfer:** Low rates of growth in patents and licensing agreements at Canadian higher education institutions 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.
- **Business support:** New ventures in Canada receive relatively little direct public funding support for development and commercialization of new technologies.
- **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 appear to be risk averse relative to their U.S. counterparts.

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.

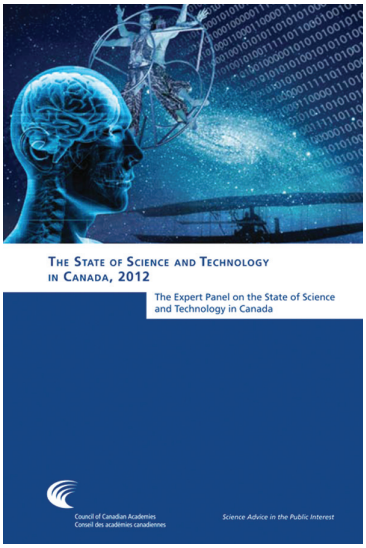
CONCLUSIONS

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 IR&D excellence. 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.

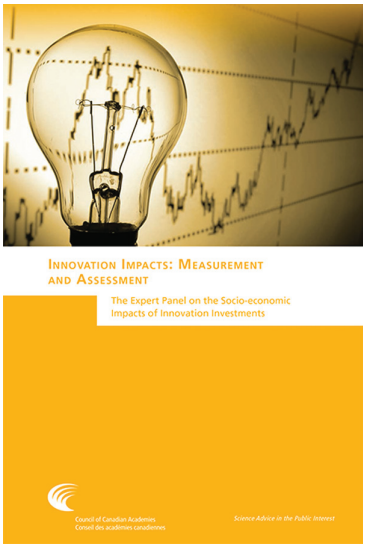
Inevitably, the future commercial successes or failures in many industries will hinge on the extent to which Canadian firms are capable of adopting, developing, and marketing world-leading technologies. Building a strong foundation of IR&D is an essential part of developing that capacity for the future,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

OTHER COUNCIL REPORTS THAT MAY BE OF INTEREST ARE:

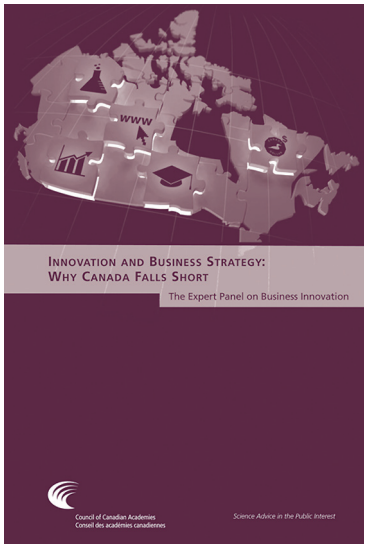
The State of Science and Technology in Canada, 2012



Innovation Impacts: Measurement and Assessment



Why Canada Falls Short: Innovation and Business Strategy



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