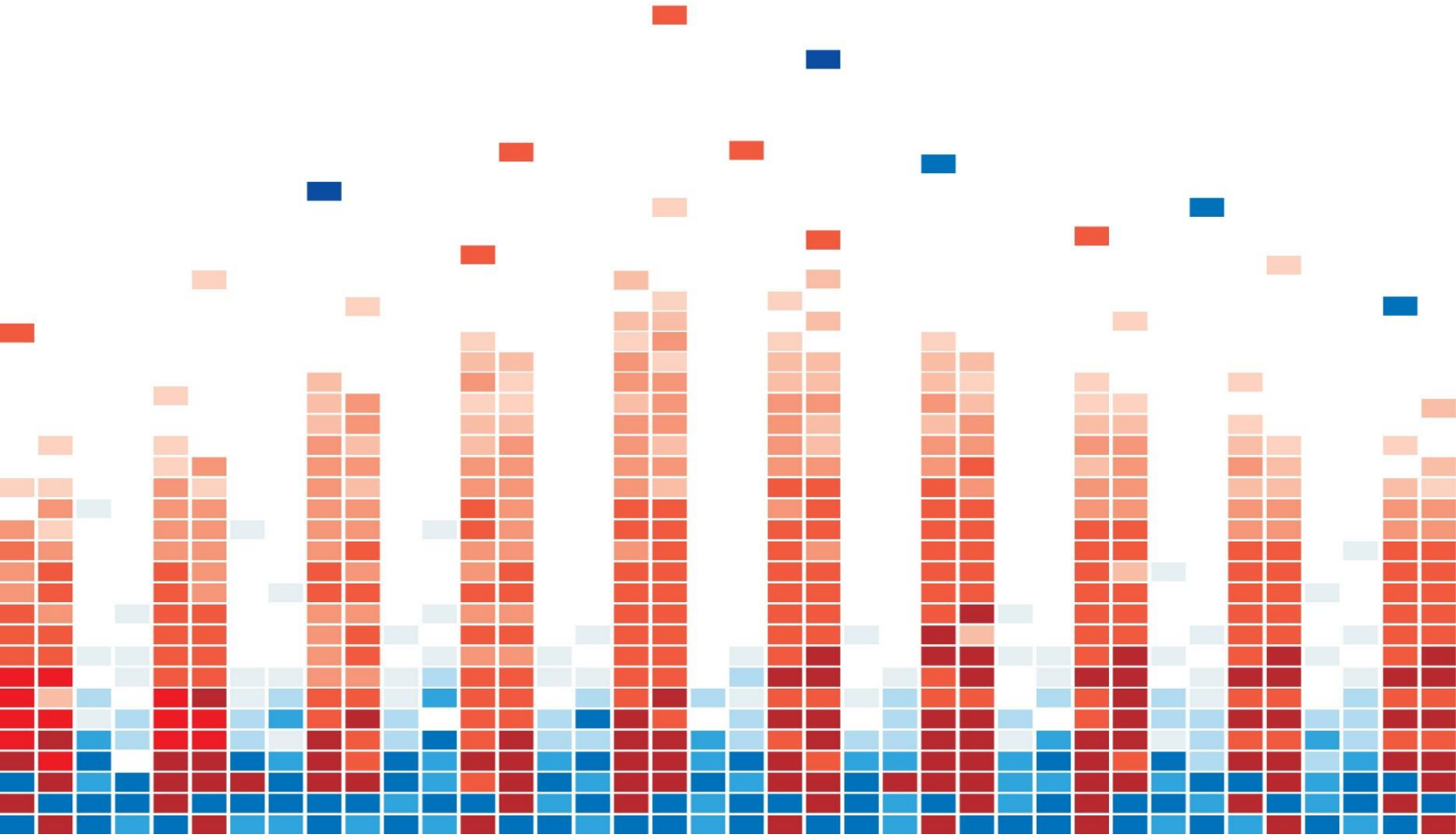
Science-Metrix

# Bibliometric Analysis for the Expert Panel on the State of Science & Technology in Canada 2025

## Final report



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# Bibliometric Analysis for the Expert Panel on the State of Science & Technology in Canada 2025

## Final report

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# Executive summary

The Council of Canadian Academies (CCA) mandated Science-Metrix to re-evaluate the current state of Canada's scientific and technological production by analyzing data from scientific publications and patented inventions, as previously in 2006, 2011, and 2016. This report focuses on the period 2012–2023. The key findings are summarized below.

## Scientific production of Canada

- Canada published 813,000 publications between 2012–2023 and ranked 11th globally by fractional counting, a decline from 9th place in the previous study. Canada was overtaken by Russia and the Republic of Korea over the last decade.
- Canada was involved in 1,228,000 publications (by full counting) between 2012–2023 and ranked 9th globally, a decline from 7th place in the previous study. Canada was overtaken by India and Italy over the last decade.
- Canada's growth in scientific output was modest, with a GR of 1.09 compared to the worldwide GR of 1.37, ranking Canada 12th among the top 20 most publishing countries but above most non-emerging nations.
- In terms of impact, Canada ranked 6th among leading countries based on all citation-related metrics. With an ARC of 1.17, a CDI of 5.7, an $HCP_{10\%}$ of 11.8%, and an FWCS of 1.30, Canada exceeded global averages on all citation metrics.
- Canada's rank based on composite indicator score was 10th, due in part to underperformance on cross-disciplinarity-related metrics and increased levels of outputs and sustainable growth from emerging countries.
- Just over half (53.2%) of Canada's publications were the result of collaboration with an international researcher.
- Canadian scientists' strongest collaboration affinity among the top publishing countries is with the United States (PAI = 1.95) and Iran (PAI = 1.77), followed by China (PAI = 1.51) and Australia (PAI = 1.35).
- Canada presents with stronger asymmetrical affinity in international collaborations, compared to those countries' reciprocal affinity, for 15 out of the 19 countries assessed, indicating Canada's prominent role in initiating research partnerships with other leading countries.
- As observed in the previous study, Canada continued to publish most in Clinical Medicine journals (23.6% of all publication output) and continues to be most specialized in the fields of Public Health and Health Services (SI = 2.14) and Psychology and Cognitive Sciences (SI = 2.04). Information & Communication Technologies was Canada's highest-impact field (ARC = 1.44).
- Canada's emerging research subfields are primarily concentrated in the Health Sciences domain, with Substance Abuse showing the strongest growth ($GR_{Canada}$ = 1.89; $GR_{World}$ = 1.37). Substance Abuse, along with Dermatology & Venereal Diseases, Emergency & Critical Care Medicine, and Environmental & Occupational Health were the four subfields identified in the previous study that have persisted as emerging subfields.
- Applied Sciences–related topics stood out among the most interdisciplinary topics in Canada.

- Ontario published 42.9% of Canada's research articles, Quebec published 19.3%, British Columbia published 11.9%, and Alberta published 11.3%.
- The province which published the most impactful research is British Columbia, followed closely by Ontario.
- Interprovincial and public–private collaborations show distinct patterns across Canada: provinces typically maintained moderate public–private collaboration rates (6.8%–9.3%), while the territories had higher rates (15.9%–18.3%). Interprovincial collaboration was also highest in the territories (83.9%–89.3%), likely reflecting resource-sharing needs.

## Scientific production of the leading countries

- China[1] published nearly one quarter (22.7%) of all articles worldwide, followed by the United States (21.3%).
- Russia, China, and India grew their publication output the most over the 2012–2023 period.
- As observed in the previous study, the Netherlands, Switzerland, and Sweden published the highest impact research. They also had the highest rate of collaboration with international partners.
- The composite indicator ranked the United States 1st, China 2nd, and Switzerland 3rd.

## Technological production of Canada

- Canada ranks 8th in the world in terms of new ownership of patents in the U.S. market (USPTO patents). In the European market (EPO patents), Canada ranks 13th.
- Canada's U.S. patents received a number of citations on par with the world average (ARC = 1.00). At the European level, Canada's patents were more cited than the world average (ARC = 1.16).
- The technological production of Canada grew by only 5% between 2012–2017 and 2018–2023 (15th among leading countries), below the world average of 13%. Stronger growth was observed in the European market, with Canada's output growing by 51% between 2011–2016 and 2017–2022,[2] but still below the world level of 64%, leading to only 14th position among leading countries on this indicator.[3]
- Patented inventions created by Canadian inventors are most often owned by foreign assignees, indicating that Canada displays a deficit in terms of ownership of new technology (flow of IP of -28% at USPTO, -19% at EPO).

[1] For the purposes of this report, China includes Hong Kong and Macao but excludes Taiwan.

[2] Time periods for analyses of European patents are shifted back by one year as data were still incomplete for 2023 during preparation of the report.

[3] Strong growth in patents at the EPO appear to come from multiple sources, including treatment of a large backlog of patents in recent years. However, note that this trend has reversed since 2021, as a combined effect of emptying the backlog, the COVID pandemic, and a focus on patent quality over quantity. Still, this is only reflected in patent counts, as patent applications have kept increasing in recent years (https://www.epo.org/en/about-us/statistics/patent-index-2023)

- Canada ranks 9th among leading countries according to the composite indicator score at the USPTO, a decline from 4th in the previous study.[4] In the European market, Canada ranks 15th among leading countries.
- The majority of Canada's patents were in the field of Electrical Engineering, although patenting activity in this field declined over the period. This is mostly due to the decline observed for BlackBerry, which accounted for 13% of all Canadian patents across all fields, but 31% of all Canadian patents under Electrical Engineering. At the European level, Canada's dependency on BlackBerry was even stronger; the company accounting for 31% of all Canadian EPO patents across all fields, but 66% in Electrical Engineering.
- Ontario owns over half of Canada's total technological output, and the majority of cities among Canada's top 50 cities based on ownership of patent counts are in Ontario. However, there was an overall decline in Ontario's patenting activity over the period, again linked to BlackBerry.
- Using USPTO data, except for Ontario (GR = 0.87), Manitoba (GR = 0.97) and Prince Edward Island (GR = 0.81), all the other provinces increased their patent count. Quebec was notable on that front with the 4th largest increase (GR = 1.41), combined with the 2nd largest output.
- Nova Scotia stands out with by far the largest increase between 2011–2016 and 2017–2022 (+167%). With the highest GR and ARC, Nova Scotia ranked highest based on composite indicator score.
- BlackBerry continued to be the biggest contributor of all new Canadian technology, acquiring 7,400 (almost 13%) of all patents; however, there has been a steep decline in patenting activity over the period (GR = 0.23). Pratt & Whitney followed, contributing 1,600 (2.8%) of Canada's patent portfolio. In the European market, Blackberry accounted for 31% of all Canadien patents (~4,000 patents). Pratt & Whitney again came 2nd, with 190 patents (1.4%).

### Technological production of the leading countries

- The United States acquired 49.7% of all new patents at the USPTO, followed by Japan which acquired 16.1% of all new patents. The United States also had the highest impact patents with an ARC of 1.33.
- In the European market, the United States still ranked 1st, but the lack of home-field advantage was reflected in its lower share of patents at 23.8%. Germany ranked 2nd with 17.5%, followed by Japan (16.2%) and France (6.8%). Countries ranking high across both markets include, in addition to the United States and Japan, South Korea (3rd at USPTO, 5th at EPO), Germany (4th at USPTO, 2nd at EPO), and China (5th at USPTO, 7th at EPO).
- Taiwan's positioning in the U.S. market was notably strong, ranking 6th; at the EPO Taiwan was only 17th. This reflects the strong ties between both nations, and the strategic importance of Taiwan in critical technologies for the United States.
- China grew its patenting activity the most in both markets, with a GR of 2.78 at the USPTO and 4.56 at the EPO, significantly surpassing the global rates.

[4] The composition of the composite indicator was modified since the last edition, discretion is thus advised when making direct comparisons. However, as other countries have emerged in terms of output, growth and impact, it appears clear that the change in ranking observed is supported by a decline in Canada's standing in the patenting ecosystem.

- The composite indicator ranked the United States 1st, Cayman Islands 2nd and China 3rd at the USPTO. The Cayman Islands' high ranking was due to its flow of IP of 10,514%, a reflection of its role as a tax haven.
- At the EPO, the composite indicator ranked the United States 1st again, this time followed by Germany and Japan.

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# Acronyms

| | |
|---|---|
| ARC | Average of relative citations |
| CCA | Council of Canadian Academies |
| CI | Collaboration index |
| CDC | Citation distribution chart |
| CDI | Citation distribution index |
| CMA | Census Metropolitan Area |
| EPO | European Patent Office |
| FWCS | Field-weighted CiteScore |
| GI | Growth index |
| GR | Growth rate |
| HCP10% | Highly cited publications in 10% most cited |
| IF | Impact factor |
| IP | Intellectual property |
| PAI | Probabilistic affinity index |
| PATSTAT | Worldwide Patent Statistical Database |
| PPP | Public–private partnership |
| RC | Relative citations |
| S&T | Science & Technology |
| SI | Specialization index |
| USPTO | United States Patent and Trademark Office |

# 1 Introduction

Since 2006, the Council of Canadian Academies (CCA) has performed assessments of the state of science & technology (S&T) in Canada to provide insights about Canada's strengths and weaknesses in terms of S&T novelty and innovation, its position in and contribution to the global S&T community, and emerging markets, technologies and players on the global scene. The findings from these assessments are intended to provide policymakers and stakeholders with the necessary guidance required to produce effective public policy.

The CCA established an expert panel comprising specialists from a variety of disciplines and backgrounds to ensure an authoritative, credible and independent assessment of the state of S&T in Canada. This present 2025 report is designed to support the work of this panel. It builds upon and updates the last three reports on *The State of Science and Technology in Canada*, released in 2006, 2012 and 2018, which outlined Canada's strengths and weaknesses in S&T by analyzing a variety of scientometric (i.e. pertaining to scientific publications) and technometric (i.e. pertaining to patented inventions) indicators to shed light on the state of research and innovation in Canada, its provinces and territories, and other countries that lead in S&T. This updated report covers the period from 2012 to 2023 and delivers a similar analysis with up-to-date data; its goal is to shed light on Canada's position relative to global peers in terms of its authorship of scientific publications and its ownership of patents, analyze such trends over recent years and identify the scientific and technological fields where Canada is a leader. In addition, the current edition includes data for Canadian cities, which help to identify important innovation hubs in Canada. These analyses will inform the CCA Expert Panel's comprehensive review of the state of science, technology and innovation in Canada.

## 1.1 Objectives

In order to assess the current state of S&T in Canada, the following questions are proposed as guidance:

- Considering both basic and applied research fields, what are the scientific disciplines and technological applications in which Canada excels?
- How are these strengths distributed geographically across the country (by province and territory as well as by city)?
- How does Canada's performance compare with what has been taking place in countries with similar S&T profiles?
- In which scientific disciplines and technological applications has Canada shown the strongest improvement/decline in the last five years?
- What major trends have emerged?
- Which scientific disciplines and technological applications have the potential to emerge as areas of prominent strength for Canada?

To answer these questions, a thorough analysis of scientific and technological databases is necessary. The state of science is measured with data from a bibliographic database of scientific journal publications. For the purposes of this project, the Scopus database (operated by Elsevier) is used. The measurement of the state of technological innovation is made possible by analyzing patent applications. Contrary to the 2016

study where only patents from the USPTO (United States Patent and Trademark Office) were analyzed, the scope of the current report was expanded to also include data from the European Patent Office (EPO). Such information is available in databases such as the Worldwide Patent Statistical Database (PATSTAT, operated by the European Patent Office), which indexes patent applications from multiple patenting offices around the world, and the PatentsView database which builds on USPTO bulk download files.

# 2 Scientometric analysis

This section presents a global landscape of the scientific performance of the world's leading countries, Canada and its provinces and territories, measured by their scientific publications. Section 2.1 presents bibliometric statistics for the top publishing countries in the world. Section 2.2 focuses on the performance of Canada's provinces and territories across 20 major fields of science. Section 2.3 provides a cluster-based assessment of Canada's strengths in highly interdisciplinary fields, Section 2.4 focuses on the scientific performance of Canada's leading institutions, and finally, Section 2.5 assesses the scientific performance of a selection of Canadian CMAs.

## 2.1 Scientific performance of the world's leading countries

In this subsection, we focus our attention on the scientific performance of the world's 20 leading countries based on the number of scientific articles[5] their scientists published from 2012 to 2023. Additional information on the performance of these countries that is not covered in this report is available in the accompanying Excel databook.

### 2.1.1 Scientific output and impact

The worldwide scientific community produced over 34 million scientific articles between 2012 and 2023 (Table I). China published the most, with 7.1 million articles based on fractional counting (20.7% of worldwide total), replacing the United States (5.7 million articles; 16.8%) as the leader in research output for the first time since *The State of Science and Technology in Canada* reports have been commissioned.[6,7] Four countries trail the United States by approximately 4 million articles, having published 1–2 million articles during the period: India (1.7 million articles; 5.0%), Germany (1.4 million articles; 4.1%), the United Kingdom (1.4 million articles; 4.0%) and Japan (1.3 million articles; 3.7%). Canada ranks in 11th place with 813,000 publications (2.4%), surpassed by Italy (996,000 articles; 2.9%), Russia (907,000 articles; 2.7%); France (894,000 articles; 2.6%), and South Korea (833,000; 2.4%). Canada surpassed Spain (803,000; 2.4%) by just 10,000 articles. Canada slipped from 7th to 11th position since the 2016 report. Based on yearly scientific output, Spain has consistently published more than Canada since 2019. Brazil, which published 764,000 articles during the period (2.2%) surpassed Canada in terms of publication output from 2019–2021.

Canada's decline in position based on fractional publication count reflects its weaker level of publication growth relative to other countries among the top 20. Canada increased its scientific output by 9% between 2012–2017 and 2018–2023 (GR = 1.09; Table I). In this regard, Canada is more similar to the United States and a number of countries in Europe (United States GR = 1.05; United Kingdom GR = 1.05; Netherlands GR = 1.06; Sweden GR = 1.07; Switzerland GR = 1.09; Australia GR = 1.12). In contrast,

[5] The selection is based on the number of publications using fractional counting.

[6] China's annual output passed that of the United States in 2017.

[7] China also leads when relying on the full counting approach, but the gap with the United States becomes much smaller, both being respectively involved on 22.7% and 21.3% of all publications over the study period.

Russia, China, and India had the highest growth ratios (Russia GR = 1.88; China GR = 1.84; India GR = 1.81) while Japan's GR of 1.00 reflects a steady state and France saw a decline in publication output with a GR of 0.94. Canada's GR is overall lower than the worldwide level (GR = 1.37), reflected by a GI value of 0.80. The GI score is the GR relative to the world; a GI greater than 1 indicates stronger growth than the worldwide growth, while a GI below 1 indicates the reverse. The high worldwide GR is mainly driven by Russia, China and India's high GR, which all have a GI above 1.30. Aside from these leaders in growth, only Iran (GI = 1.10) and Turkey (GI = 1.04) have a GI above 1.00.

While Canada ranks relatively low among leading countries in terms of growth (12th), it still ranks higher than most other historically leading countries, being mostly surpassed by emerging nations. This finding is relevant to better contextualize Canada's observed growth, which might be better compared with established top publishing nations like Switzerland, Germany, the Netherlands, the United States, the United Kingdom, Japan and France, which all presented with lower growth than Canada over the last 12-year period.

With regards to collaboration rate, it is worth mentioning that the full counting of publications produces a different ranking, with Canada ranking in the 9th position, now ahead of both Russia and South Korea (Table I). This reflects the higher international collaboration rate of Canada compared with Russia and South Korea (hence decreasing the share given to Canada when using fractional counting). A similar trend is observed for Australia and Netherlands, which move up by 3 positions based on full counting compared with fractional counting (Australia moves from 14th to 11th position; Netherlands moves from 18th to 15th position). Along with Russia and South Korea, India and Turkey also declined in rank by two positions (3rd to 5th position and 16th to 18th position, respectively). All four countries have international collaboration rates (ICR) below 25% while Canada's international collaboration rate is 53.2% (more detail on international collaboration is presented in Section 2.1.3).

Table I Scientific performance of the world's leading countries in all fields of science (2012–2023)

| Country | Scientific output | | | | | Scientific impact | | | | | Cross-disciplinary | | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FRAC* | FULL | Trend (FRAC) | GR* (FRAC) | GI (FRAC) | ARC* | CDI | CDC | $HCP_{10\%}$* | FWCS | DDR10* | DDA10* | Score | Rank |
| **World** | **34,147,501** | **34,147,501** | | **1.37** | **1.00** | **1.00** | **0.0** | | **10.0%** | **1.00** | **0.10** | **0.10** | **n.c.** | **n.c.** |
| China | 7,064,285 | 7,743,955 | | 1.91 | 1.40 | 0.96 | -1.5 | | 10.0% | 0.97 | 0.09 | 0.08 | 0.65 | 2 |
| United States | 5,726,880 | 7,259,342 | | 1.05 | 0.77 | 1.29 | 6.2 | | 13.7% | 1.33 | 0.09 | 0.11 | 0.71 | 1 |
| India | 1,692,773 | 1,897,047 | | 1.81 | 1.33 | 0.78 | -5.0 | | 7.1% | 0.79 | 0.10 | 0.10 | 0.50 | 9 |
| Germany | 1,404,636 | 2,034,495 | | 1.07 | 0.78 | 1.07 | 1.7 | | 10.8% | 1.22 | 0.09 | 0.10 | 0.41 | 11 |
| United Kingdom | 1,369,075 | 2,189,647 | | 1.05 | 0.77 | 1.30 | 6.9 | | 14.0% | 1.35 | 0.11 | 0.12 | 0.52 | 7 |
| Japan | 1,279,154 | 1,537,881 | | 1.00 | 0.73 | 0.73 | -7.0 | | 5.9% | 0.99 | 0.07 | 0.07 | 0.23 | 20 |
| Italy | 996,326 | 1,365,995 | | 1.27 | 0.93 | 1.07 | 4.7 | | 10.8% | 1.12 | 0.10 | 0.12 | 0.52 | 8 |
| Russia | 907,449 | 1,050,773 | | 1.88 | 1.38 | 0.38 | -22.2 | | 2.1% | 0.61 | 0.11 | 0.08 | 0.30 | 19 |
| France | 894,186 | 1,361,072 | | 0.94 | 0.69 | 0.96 | -0.9 | | 9.4% | 1.19 | 0.09 | 0.11 | 0.37 | 17 |
| Rep. of Korea | 833,106 | 999,840 | | 1.23 | 0.90 | 0.89 | -0.9 | | 8.1% | 1.07 | 0.09 | 0.09 | 0.35 | 18 |
| **Canada** | **812,794** | **1,227,990** | | **1.09** | **0.80** | **1.17** | **5.7** | | **11.8%** | **1.30** | **0.10** | **0.11** | **0.44** | **10** |
| Spain | 802,787 | 1,130,522 | | 1.22 | 0.89 | 0.95 | 0.9 | | 9.1% | 1.12 | 0.09 | 0.10 | 0.41 | 14 |
| Brazil | 764,250 | 919,935 | | 1.31 | 0.96 | 0.70 | -6.4 | | 5.4% | 0.87 | 0.10 | 0.12 | 0.40 | 15 |
| Australia | 725,044 | 1,115,923 | | 1.12 | 0.82 | 1.26 | 8.3 | | 13.4% | 1.31 | 0.11 | 0.13 | 0.53 | 5 |
| Iran | 586,981 | 671,012 | | 1.51 | 1.10 | 0.88 | -0.6 | | 8.7% | 0.80 | 0.11 | 0.13 | 0.52 | 6 |
| Turkey | 479,948 | 568,450 | | 1.42 | 1.04 | 0.72 | -6.8 | | 6.1% | 0.77 | 0.11 | 0.11 | 0.41 | 12 |
| Poland | 450,466 | 572,020 | | 1.27 | 0.93 | 0.65 | -8.4 | | 4.6% | 0.89 | 0.12 | 0.11 | 0.39 | 16 |
| Netherlands | 418,493 | 696,637 | | 1.06 | 0.78 | 1.38 | 10.4 | | 15.2% | 1.42 | 0.10 | 0.12 | 0.61 | 4 |
| Taiwan | 379,267 | 471,533 | | 0.95 | 0.69 | 0.86 | -0.1 | | 7.7% | 1.12 | 0.10 | 0.12 | 0.41 | 13 |
| Switzerland | 290,001 | 539,743 | | 1.09 | 0.80 | 1.33 | 7.5 | | 14.5% | 1.44 | 0.09 | 0.12 | 0.62 | 3 |

Note: n.c.: not calculated. The top 20 most publishing countries were selected using fractional counting. The scale in the trends is not the same across countries.
FRAC: fractional counting; FULL: full counting
Impact indicators (ARC, CDI, HCP10, FWCS, and CDI) are not calculated for groups with fewer than 30 papers that have a relative citation (RC) score. Only papers published in 2021 or earlier have an RC score. Indicators were normalized by subfield and year and against the world level.
Cross-disciplinary indicators (DDR, DDR10, DDA, and DDA100) were normalized by subfield, document type and by year.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red) in output.
The composite indicator uses the indicator marked with '*', using the following weight: number of publications (FRAC; 20%), GR (10%), SI (value of 1 in all fields of science; 15%), ARC (20%), HCP10 (10%), DDA10 (10%), and DDR10 (10%).

Source: Computed by Science-Metrix using data from Scopus

The average relative citation (ARC) score of countries among the top 20 ranged from 0.38 for Russia to 1.38 for Netherlands. With an ARC of 1.17, Canada ranks 6th among the top 20 countries. Along with the Netherlands, Canada is surpassed by Australia, the United States, the United Kingdom, and Switzerland, all of which had an ARC within the range of 1.25–1.33. The countries with scores within 0.15 points of the world level were Italy, Germany, France, China, Spain, South Korea, Iran and Taiwan. India, Japan, Turkey, and Brazil follow with an ARC in the range of 0.7–0.8, while Poland's ARC of 0.65 sets it well above that of Russia. When a country is growing quickly, as is the case for China, India, and Russia, the "quality" or "impact" of its scientific papers often diminishes due to numerous factors. However, when this growth slows, the impact measure usually increases. This can be observed for China and India. China has seen its ARC increase from 0.86 in 2012–2017 to 1.05 in 2018–2021 while the ARC of India increased from 0.75 in 2012–2017 to 0.81 in 2018–2021 (data available in the accompanying Excel databook). China is of particular note because the 0.19-point increase achieved between the periods represents the largest increase in ARC among the 20 countries. The citation impact of Russia, which increased by 0.02 points may similarly be expected to increase over time. The United States saw the biggest decline in ARC with a 0.10 point decline between the period. Canada follows with a decline in ARC from 1.20 in 2012–2017 to 1.12 in 2018–2021. Because the fractionalized version of the ARC is used to benchmark countries, there is a zero-sum game in action with the indicator, with increases for countries with large numbers of publications necessarily leading to decreases elsewhere, as the world average remains centered around 1.00. Thus, the increasing number of citations to China's and India's publications thus leads to decreases for other nations, reflecting the fact that the gap in citations between leading countries and emerging actors is slowly closing.

The citation distribution chart together with the citation distribution index (CDI) provide a way to assess the distribution of the publication portfolio based on relative citation impact. Values reflect the distribution of publications relative to expected trends based on the global distribution. CDI values above 0 reflect a skew towards more highly cited publications while values below 0 reflect a skew towards less cited publications. With a CDI of 5.7, Canada's CDI reveals publications in the portfolio are more abundant than expected in the top citation deciles and less represented than expected in the bottom citation deciles. As with ARC, Canada ranks in the 6th position based on CDI and is surpassed by the same 5 countries that surpass Canada based on ARC. One notable difference observed in the CDI ranking is that Australia ranks 2nd, respectively based on CDI rather than 5th based on ARC. This indicates the presence of much higher-than-expected publication counts in the highest deciles, an observation that is also reflected in the share of highly cited papers ($HCP_{10\%}$). Consistent with observations based on ARC, Russia has the lowest CDI among the 20 countries (CDI = -22.23), with higher-than-expected counts of publications in the four lowest deciles.

In terms of publications in the top 10 percentiles based on citation impact ($HCP_{10\%}$), 9 of the 20 countries assessed exceeded global levels with more than 10% of their publications in the top 10 percent (Table I). The Netherlands and Switzerland lead with approximately 15% of their publications among the top 10 percent most cited. The United Kingdom, the United States, Australia and Sweden follow with $HCP_{10\%}$ ranging from 12.9–14.0%. Canada's $HCP_{10\%}$ of 11.8% places it at the 6th position, above Italy and Germany (both with $HCP_{10\%}$ = 10.8%). China's $HCP_{10\%}$ of 10% is just on par with the expected world level. Notably, China's $HCP_{10\%}$ has rapidly risen over the period and has surpassed the expected world

level during the period 2018–2021. Countries with $HCP_{10\%}$ below the expected world level are France ($HCP_{10\%}$ = 9.4%), Spain ($HCP_{10\%}$ = 9.1%), Iran ($HCP_{10\%}$ = 8.7%), Taiwan ($HCP_{10\%}$ = 7.7%), , India ($HCP_{10\%}$ = 7.1%), Turkey ($HCP_{10\%}$ = 6.1%), Japan ($HCP_{10\%}$ = 5.9%), Brazil ($HCP_{10\%}$ = 5.4%), Poland ($HCP_{10\%}$ = 4.6%), and Russia ($HCP_{10\%}$ = 2.1%). The CDC distribution charts in Table I visually reflect this dynamic, with countries that score high in $HCP_{10\%}$ also having the last deciles of the distribution in positive (green) territory while the first deciles are negative (red), and vice versa for countries with a lower $HCP_{10\%}$ score.

Field-weighted CiteScore (FWCS) values tend to correlate well with ARC and $HCP_{10\%}$, since articles in high impact journals tend to present with higher odds of being highly cited. It is therefore unsurprising that Canada places 6th based on FWCS, as it did based on ARC, $HCP_{10\%}$, and CDI. Indeed, the ranking of countries based on FWCS largely mirrored that observed for other citation-based indicators.

### 2.1.2 Cross disciplinarity and composite indicator

To provide insights into the cross-disciplinarity represented in the research portfolio of the countries, the share of papers among the top 10% based on disciplinary diversity of references (DDR10) and the share of papers among the top 10% based on disciplinary diversity of authors (DDA10) was computed for the 20 countries in this study (Table I). DDR10 reveals a very tight range among the countries, from 8.6% for Germany to 12.1% for Poland. Japan was the exception among the countries with a DDR10 of only 7.3%, placing it well outside of that range. Japan's DDA10 scores were similarly low, indicating that Japan has very low levels of cross-disciplinarity as represented by both the research itself and the participating authors. Canada's DDR10 of 9.6% was just below the expected level of 10% although its DDA10 of 10.9% indicates much more collaboration between authors of different disciplines than expected based on global levels. Iran stands out as a leader in cross-disciplinarity with a consistently high position across both DDR10 and DDA10 (DDR10 = 11.2%; DDA10 = 12.8%).

A composite indicator (CI) is a useful tool to compare entities, as it provides a single indicator that accounts for both scientific production and impact. The composite indicator takes the form of a score, with 1.00 representing a perfect score, where an entity presents with the highest scores across all indicators. The composite indicator computed to provide insights into scientific performance across all fields of science accounts for the number of publications (based on fractional counting; 20% weight), GR (10% weight), SI (15%), ARC (20% weight), $HCP_{10\%}$ (15% weight), DDA10 (10% weight) and DDR10 (10% weight). In analyses across all fields, specialization index (SI) stands at 1.00 for all entities, resulting in an equal contribution of 0.15. According to this measure, the United States ranks 1st (Table I, CI Score = 0.71). China, Switzerland, and the Netherlands follow with CI scores in the range of 0.61–0.65. Australia, Iran, the United Kingdom, Italy and India all had CI scores within 0.03 points of each other (ranging from 0.50 to 0.53). In 10th place, Canada had a score of 0.44, placing just above Germany, Turkey, Taiwan and Spain, which all had a score of 0.41. Japan, with a score of 0.22, had the lowest score.

### 2.1.3 Collaboration and affinities

To gain a deeper understanding of the countries' approach to research, collaboration and disciplinary diversity were investigated. In addition, the pairwise probabilistic affinity index for collaborations

involving Canada were assessed to provide an understanding of the nature of Canada's research partnerships.

Roughly half of Canada's publications are the result of collaboration with authors from other countries (International Collaboration Rate (ICR) = 53.2%; Table II). The United Kingdom, Australia, France, Germany, Spain and Italy seem to take a similar approach to international collaboration as Canada with ICRs ranging from 46–58%, above the world average across all countries of 40.2%.[8] With 60–70% of publications resulting from international collaboration, Switzerland, Sweden, and Netherlands have the highest ICR. Among the 20 countries assessed, Poland (ICR = 33.1%) was the only European country with an ICR below the world country average. International collaboration rates and citation-based metrics (ARC, CDI, $HCP_{10\%}$) often correlate. In this regard, the United States (ICR = 36.0%) is notable, with an ICR below the world country average despite exceeding global levels based on citation-based metrics. This discrepancy shows that the United States is able to achieve a high citation impact in the absence of the international collaboration rates of its peers. Russia, India and China had the lowest collaboration rates, which may partially explain the lower citation-based scores of these countries.

Probabilistic affinity index (PAI) (Table II) identifies preferential research partnership within the global co-publication network, allowing the identification of strong relationships between countries while taking into account each country's relative publication output. Among the 19 countries that were assessed, Canada's strongest collaboration partners as measured by PAI are the United States (PAI = 1.95), and Iran (PAI = 1.77). China and Australia also stand out for their strong partnership with Canada with PAI of 1.51 and 1.35, respectively. Canada's PAI with the United Kingdom and France, two historically relevant partners of Canada, was only just above what would be expected, at 1.09 and 1.14, respectively. Canada's collaboration strength is the weakest with Russia (PAI = 0.60), Turkey (PAI = 0.64) and Poland (PAI = 0.64). Affinity can be asymmetrical because collaborations are often driven by leading (proxied with corresponding) authors who invite others to contribute to the research. $PAI_{asym}$ provides insight into collaboration partners when Canada leads the collaboration versus when Canada is a contributor to the research. In this regard, it is interesting to note that in research with 13 of the 19 countries, Canada presents with stronger affinity when leading compared to when it simply contributes. Notable exceptions to this include Iran ($PAI_{asym}$ Canada leads = 1.79; $PAI_{asym}$ Canada participates = 2.18) and Brazil ($PAI_{asym}$ Canada leads = 1.23; $PAI_{asym}$ Canada participates = 1.41), which tended to act more frequently as leaders in research Canada contributed to. The United States ($PAI_{asym}$ Canada leads = 2.24; $PAI_{asym}$ Canada participates = 1.84) stands out as the collaboration partner that Canada preferentially selects for partnership when leading, more than it is invited by the United States to participate, although the level of collaboration is overall much higher than expected. The imbalance with Russia was similarly high ($PAI_{asym}$ Canada leads = 0.48; $PAI_{asym}$ Canada participates = 0.36). In collaborations with the largest producer of research, China, $PAI_{asym}$ when Canada leads was well above the $PAI_{asym}$ for when Canada participates ($PAI_{asym}$ Canada leads = 1.19; $PAI_{asym}$ Canada follows = 0.73).

[8] The world average is the weighted average across all countries, which is a better comparator against which to position countries than the share of publications involving at least two countries. That second metric stands in the low 20% because of the high volume of single-country publications coming out of China and India.

Table II Collaboration trends of the world's leading countries in all fields of science (2012–2023)

| Country | Output | Collaboration | | | | | |
|---|---|---|---|---|---|---|---|
| | FULL | ICR | Avg. No. Countries | PAI | $PAI_{asym}$ (Canada leads) | $PAI_{asym}$ (Canada participates) | PPP |
| **World** | **34,147,501** | **40.2%** | **1.3** | **n.c.** | **n.c.** | **n.c.** | **6.3%** |
| China | 7,743,955 | 19.1% | 1.3 | 1.51 | 1.19 | 0.73 | 8.1% |
| United States | 7,259,342 | 36.0% | 1.6 | 1.95 | 2.24 | 1.84 | 8.7% |
| India | 1,897,047 | 20.4% | 1.4 | 0.83 | 0.75 | 0.74 | 3.5% |
| Germany | 2,034,495 | 50.6% | 2.2 | 0.88 | 0.70 | 0.66 | 11.3% |
| United Kingdom | 2,189,647 | 57.6% | 2.3 | 1.09 | 0.98 | 0.91 | 9.0% |
| Japan | 1,537,881 | 28.5% | 1.6 | 0.93 | 0.76 | 0.64 | 11.1% |
| Italy | 1,365,995 | 46.3% | 2.2 | 0.79 | 0.61 | 0.58 | 8.2% |
| Russia | 1,050,773 | 23.0% | 1.6 | 0.60 | 0.48 | 0.36 | 4.3% |
| France | 1,361,072 | 54.9% | 2.3 | 1.14 | 1.06 | 1.11 | 9.0% |
| Rep. of Korea | 999,840 | 29.3% | 1.6 | 0.78 | 0.66 | 0.65 | 9.3% |
| **Canada** | **1,227,990** | **53.2%** | **2.1** | **n.c.** | **n.c.** | **n.c.** | **8.1%** |
| Spain | 1,130,522 | 48.0% | 2.2 | 0.73 | 0.53 | 0.53 | 6.4% |
| Brazil | 919,935 | 32.0% | 1.8 | 1.18 | 1.23 | 1.41 | 3.6% |
| Australia | 1,115,923 | 55.7% | 2.2 | 1.35 | 1.31 | 1.23 | 6.6% |
| Iran | 671,012 | 26.7% | 1.5 | 1.77 | 1.79 | 2.18 | 2.2% |
| Turkey | 568,450 | 24.8% | 1.8 | 0.64 | 0.57 | 0.68 | 2.9% |
| Poland | 572,020 | 33.1% | 2.1 | 0.64 | 0.56 | 0.53 | 4.7% |
| Netherlands | 696,637 | 61.5% | 2.7 | 0.96 | 0.81 | 0.74 | 11.5% |
| Taiwan | 471,533 | 27.7% | 1.8 | 0.74 | 1.08 | 0.58 | 5.3% |
| Switzerland | 539,743 | 68.9% | 3.0 | 0.92 | 0.78 | 0.81 | 13.8% |

Note: n.c.: not calculated. The top 20 most publishing countries were selected using fractional counting. FULL: full counting
Collaboration: The ICR for the world is weighted. Not all publications could be coded by sector. Publications involving the public sector include at least one author not affiliated with a for-profit organization. PPP stands for public–private partnership and represents the share of publications in collaboration with for-profit organizations.
Source: Computed by Science-Metrix using data from Scopus

## 2.2 Scientific performance of Canada's provinces and territories

In this subsection, we explore the scientific performance of Canada's provinces and territories. The attribution of a province or territory to an address on a publication is defined by the city, postal code and the affiliation given by the authors. Note that not all addresses could be attributed to a province or territory as some records omit the city, some contain typographical errors and some affiliations are simply unidentifiable, among other issues. Nonetheless, more than 96% of Canadian addresses were assigned to a province or territory.

### 2.2.1 Scientific output, impact and cross-disciplinarity

The scientific output and impact of the provinces and territories is presented in Table III. The production of scientific articles in Canada is dominated by Ontario. Its 348,000 publications (fractional count) accounts for 42.9% of Canada's total output between 2012 and 2023. Quebec follows with 157,000 publications (19.3%). British Columbia ranks 3rd with 96,000 publications (11.9%), followed closely by

Alberta with 92,000 publications (11.3%). Nova Scotia, Saskatchewan, and Manitoba all have similar scientific production, with 20,000–25,000 publications each (2.5% to 3.0%). Newfoundland and Labrador (11,000 publications; 1.3%), New Brunswick (9,000 publications; 1.1%), Prince Edward Island (1,600 publications; 0.2%), and the territories (500 publications combined; 0.1%) finish the ranking. The ranking of provinces according to full counting of publications is identical to the ranking based on fractional counting.

The fractional GR was similar for all provinces to Canada's (GR = 1.09), except for Newfoundland and Labrador (GR = 1.20) and Prince Edward Island (GR = 1.18), which exceeded the GR of Canada. The GR of the three territories also exceeded that of Canada, ranging from 1.14 to 1.30, with the highest GR achieved by Yukon. Still, these led to relatively small increases in output given the lower publication counts associated with the territories. Although all provinces and territories had a positive growth trend over the period, none had a GR above the world level (GI > 1).

Assessing the scientific impact based on citation-based indicators reveals a large range across the provinces and territories. The highest ARC was achieved by British Columbia (ARC = 1.24) followed by Ontario (ARC = 1.22). Both provinces also lead in terms of highly cited publications with $HCP_{10\%}$ of 13.2% and 12.4% for British Columbia and Ontario, respectively. Quebec and Alberta both have an ARC of 1.15 and $HCP_{10\%}$ of 11.7% and 11.4%, respectively, putting them just below Canada on both metrics (Canada's ARC = 1.17; $HCP_{10\%}$ = 11.8%). The provinces and territories with an ARC below the world level were New Brunswick (ARC = 0.93), Yukon (ARC = 0.88), Prince Edward Island (ARC = 0.88), and Nunavut (ARC = 0.80). Northwest Territories and Saskatchewan had an ARC equivalent to the global average of 1.00. All provinces and territories that had an ARC of 1 or less had an $HCP_{10\%}$ that was below the expected 10%. Manitoba, Newfoundland and Labrador, and Nova Scotia had an ARC just above the world average (ranging from 1.03–1.04) and $HCP_{10\%}$ just above the expected level (ranging from 10.1–10.6%).

Despite a wide range in ARC and $HCP_{10\%}$ that spanned from below to above global levels, research from the provinces and territories tended to be published in high impact journals, as the FWCS of all provinces and territories was above the world standard (FWCS > 1). British Columbia published in journals with the highest impact (FWCS = 1.40), coinciding with its high ARC and $HCP_{10\%}$ values. Quebec (FWCS = 1.35), Ontario (FWCS = 1.35) and Alberta (FWCS = 1.33) followed closely behind. Prince Edward Island (FWCS = 1.10), Nunavut (FWCS = 1.11), and New Brunswick (FWCS = 1.15) tended to publish in journals with lower impact, but still above world average.

Cross-disciplinarity metrics DDR10 and DDA10 reveal trends that differ from the trends observed for scientific output and impact. For both metrics, Nunavut leads (DDR10 = 14.2%; DDA10 = 19.8%) followed by Prince Edward Island (DDR10 = 12.6%; DDA10 = 15.2%). Ontario, Quebec, British Columbia, Alberta and Manitoba, six provinces that were leaders in terms of output and impact, had DDR10 scores below the expected 10%. The lower DDR10 scores for high impact provinces are not surprising as an inverse relationship between interdisciplinarity and citations is often reported in the literature.[9] Saskatchewan, Nova Scotia, and Newfoundland and Labrador had DDR10 scores ranging

[9] https://ost.openum.ca/files/sites/132/2017/06/InterdisciplinarityVSimpactfactor.pdf

from 10.3%–10.7%. All the provinces and territories had DDA10 scores above the expected 10% with the majority ranging from 10.6%–12.8%. Nunavut, Prince Edward Island, and Northwest Territories were the exceptions with DDA10 above 15%. Further in-depth investigation of the scientific output of the leaders in cross-disciplinarity is needed to reveal whether the high DDR10 and DDA10 scores are reflective of a consistent trend across the entire corpus or mainly driven by a smaller subset of high scoring publications.

The ranking of the provinces and territories according to the composite indicator was identical to the rank based on scientific output among the top four. However, beyond the top four, some reshuffling was observed: Newfoundland and Labrador followed by Nova Scotia took the 5th and 6th positions, respectively, bumping Manitoba and Saskatchewan to 7th and 8th place, respectively. In addition, Nunavut takes the 9th position, trading places with New Brunswick, which takes the bottom position. The reshuffling based on composite indicator rank appears to be driven by GR and cross-disciplinarity metrics.

Table III Scientific performance of the Canadian provinces and territories in all fields of science (2012–2023)

| Entity | Scientific output | | | | | Scientific impact | | | | | Cross-disciplinarity | | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FRAC* | FULL | Trend (frac) | GR* (FRAC) | GI (FRAC) | ARC* | CDI | CDC | $HCP_{10\%}$* | FWCS | DDR10* | DDA10* | Score | Rank |
| **World** | **34,147,501** | **34,147,501** | | **1.37** | **1.00** | **1.00** | **0.0** | | **10.0%** | **1.00** | **10.0%** | **10.0%** | - | - |
| **Canada** | **812,794** | **1,227,990** | | **1.09** | **0.80** | **1.17** | **5.7** | | **11.8%** | **1.30** | **9.6%** | **10.9%** | - | - |
| Ontario | 348,331 | 579,528 | | 1.11 | 0.81 | 1.22 | 6.3 | | 12.4% | 1.35 | 9.4% | 10.7% | 0.71 | 1 |
| Quebec | 157,189 | 272,591 | | 1.07 | 0.78 | 1.15 | 6.4 | | 11.7% | 1.35 | 8.9% | 11.5% | 0.53 | 2 |
| British Columbia | 96,329 | 185,710 | | 1.05 | 0.77 | 1.24 | 7.4 | | 13.2% | 1.40 | 9.9% | 11.5% | 0.44 | 3 |
| Alberta | 92,195 | 169,158 | | 1.10 | 0.81 | 1.15 | 5.9 | | 11.4% | 1.33 | 9.6% | 11.8% | 0.39 | 4 |
| Manitoba | 24,602 | 48,240 | | 1.11 | 0.81 | 1.03 | 2.8 | | 10.1% | 1.24 | 9.2% | 12.7% | 0.30 | 7 |
| Saskatchewan | 22,583 | 43,520 | | 1.10 | 0.80 | 1.00 | 2.8 | | 8.9% | 1.19 | 10.7% | 12.8% | 0.29 | 8 |
| Nova Scotia | 20,519 | 43,110 | | 1.07 | 0.79 | 1.06 | 3.5 | | 10.6% | 1.27 | 10.3% | 12.4% | 0.33 | 6 |
| Newfoundland and Labrador | 10,854 | 20,194 | | 1.20 | 0.88 | 1.04 | 3.6 | | 10.2% | 1.21 | 10.6% | 12.2% | 0.36 | 5 |
| New Brunswick | 8,926 | 18,180 | | 1.06 | 0.77 | 0.93 | 0.3 | | 8.5% | 1.15 | 9.9% | 10.9% | 0.19 | 13 |
| Prince Edward Island | 1,627 | 3,647 | | 1.18 | 0.86 | 0.88 | 0.3 | | 7.5% | 1.10 | 12.6% | 15.2% | 0.28 | 10 |
| Northwest Territories | 209 | 867 | | 1.14 | 0.83 | 1.00 | 4.0 | | 9.3% | 1.24 | 8.3% | 15.2% | 0.28 | 11 |
| Yukon | 204 | 750 | | 1.30 | 0.95 | 0.88 | 0.5 | | 6.9% | 1.27 | 8.9% | 10.6% | 0.20 | 12 |
| Nunavut | 87 | 374 | | 1.16 | 0.85 | 0.80 | 3.4 | | 6.2% | 1.11 | 14.2% | 19.8% | 0.28 | 9 |

Note: n.c.: not calculated. Provinces could not be assigned to all Canadian author addresses. The scale in the trends is not the same across provinces. FRAC: fractional counting; FULL: full counting
Collaboration: The ICR for the world is a weighted average across countries. The NCR for Canada is a weighted average across provinces and territories. Not all publications could be coded by sector. Publications involving the public sector include at least one author not affiliated with a for-profit organization.
Impact indicators (ARC, CDI, HCP10, FWCS, and CDI) are not calculated for groups with fewer than 30 papers that have a relative citation (RC) score. Only papers published in 2021 or earlier have an RC score. Indicators were normalized by subfield and year and against the world level.
Cross-disciplinary indicators (DDR, DDR10, DDA, and DDA100) were normalized by subfield, document type and by year.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red) in output.
The composite indicator uses the indicator marked with '*', using the following weight: number of publications (FRAC; 20%), GR (10%), SI (value of 1 in all fields of science; 15%), ARC (20%), HCP10 (10%), DDA10 (10%), and DDR10 (10%).

Source: Computed by Science-Metrix using data from Scopus

### 2.2.2 International, interprovincial and public–private collaboration

Data for international, interprovincial and public–private collaborations for Canada and each province and territory are presented in Table IV. The provinces and territories cluster into two groups based on international co-publication rate. One group co-publishes roughly half of their scientific output with authors outside Canada. This group includes Ontario, Quebec, Alberta, Manitoba, Saskatchewan, Nova Scotia, and Prince Edward Island. The other group, consisting of the three territories, has a lower international co-publication rate, ranging from 41.7%–44.3%. British Columbia stands apart from these groups with an international co-publication rate of 57.1%. When it comes to international collaborations, a direct correlation with the impact measures is noticeable, as was the case at the country level (Section 2.1.1). However, both Northwest territories and Ontario had ARCs that were higher than would be expected based on the level of international co-publication.

The rankings of the provinces and territories based on the rate of public–private co-publication was the reverse of that observed for international co-publication, with all provinces having a relatively low rate, ranging from 6.8%–9.3% while the territories had rates ranging from 15.9%–18.3%. Interprovincial co-publication rates had a wider range (17.7%–89.3%) than observed for the other collaboration metrics. The territories had the highest interprovincial co-publication rates, ranging from 83.9%–89.3%, suggesting that the territories are too under-resourced to generate scientific output without support from other provinces. The provinces ranged in their interprovincial co-publication rate from the lowest rates of 17.7%, and 20.8% in Ontario and Quebec, respectively, to the highest rate of 50.3% in Prince Edward Island. The low interprovincial co-publication rate of Ontario and Quebec may be explained by the fact that these two provinces house more research organizations as well as a wide range of experts, thereby limiting the need for external knowledge or for equipment/infrastructure that researchers might not have access to within their own borders. However, given that both provinces did not have a similarly low international co-publication rate, it is likely that both provinces are not particularly independent, rather, when the need for collaboration arises, needs are better served by collaborations outside the country rather than with other provinces.

Table IV Collaboration trends of Canadian provinces and territories by 6-year and 12-year period (2012–2023)

| Province | International co-publication rate | | Interprovincial co-publication rate | | Public-private co-publications | |
|---|---|---|---|---|---|---|
| | % | Trend | % | Trend | % | Trend |
| **Canada** | **53.2%** | | **23.8%** | | **8.1%** | |
| Ontario | 52.3% | | 17.7% | | 8.5% | |
| Quebec | 53.5% | | 20.8% | | 8.7% | |
| British Columbia | 57.1% | | 27.8% | | 9.3% | |
| Alberta | 52.2% | | 28.6% | | 9.0% | |
| Manitoba | 48.1% | | 39.2% | | 7.9% | |
| Saskatchewan | 51.2% | | 35.0% | | 8.0% | |
| Nova Scotia | 50.6% | | 41.8% | | 7.2% | |
| Newfoundland and Labrador | 47.2% | | 35.7% | | 6.8% | |
| New Brunswick | 48.8% | | 40.1% | | 7.8% | |
| Prince Edward Island | 48.0% | | 50.3% | | 7.5% | |
| Northwest Territories | 41.7% | | 89.3% | | 18.0% | |
| Yukon | 44.3% | | 83.9% | | 15.9% | |
| Nunavut | 42.7% | | 88.0% | | 18.3% | |

Note: Provinces could not be assigned to all Canadian author addresses. The scale in the trends is not the same across provinces.
Collaboration: The NCR for Canada is a weighted average across provinces and territories. Not all publications could be coded by sector. Publications involving the public sector include at least one author not affiliated with a for-profit organization.
Source: Computed by Science-Metrix using data from Scopus

### 2.2.3 Scientific performance of Canada by fields of science

In this subsection, the performance of Canada is analyzed by field of science. Science-Metrix's scientific ontology contains 5 domains, 20 fields and 174 subfields of science, according to which most journals in Scopus are classified. The discussion in this subsection is restricted to the field level, as refining to the subfields level would result in a cumbersomely lengthy report.

#### Canada

Table V presents the performance of Canada in the different fields of science for the period 2012–2023. Canada was most active in the domain of Health Sciences (322,000 publications based on fractional counting; 39.6% of total), Applied Sciences (243,000 publications; 29.9%) and Natural Sciences (150,000 publications; 18.5%). The remaining share is split between Economic and Social Sciences (70,000 publications; 8.6%) and Arts & Humanities (28,000 publications; 3.4%). At the field level, Clinical Medicine (192,000 publications; 23.6%) accounts for Canada's largest output while all other fields account for less than 10% of Canada's output. Following Clinical Medicine, the field of Information & Communication Technologies accounts for 77,000 publications (9.5%) and Engineering accounts for 72,000 publications (8.8%).

## Table V Scientific performance of Canada by domain and field of science (2012–2023)

| Domain\Field | Scientific output | | | | | | Scientific impact | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | FRAC | FULL | Trend (frac) | GR (FRAC) | GI (FRAC) | SI | ARC | CDI | CDC | $HCP_{10\%}$ | FWCS |
| **All fields** | **812,794** | **1,227,990** | | **1.09** | **0.80** | **1.00** | **1.17** | **5.69** | | **11.8%** | **1.30** |
| **Applied Sciences** | **243,236** | **354,260** | | **1.04** | **0.73** | **0.86** | **1.25** | **7.97** | | **12.6%** | **1.29** |
| Agriculture, Fisheries & Forestry | 26,201 | 38,476 | | 1.04 | 0.69 | 1.01 | 1.24 | 8.69 | | 12.7% | 1.34 |
| Built Environment & Design | 9,223 | 12,313 | | 1.26 | 0.82 | 1.17 | 1.06 | 4.58 | | 9.8% | 1.18 |
| Enabling & Strategic Technologies | 59,023 | 87,817 | | 1.07 | 0.70 | 0.69 | 1.20 | 7.25 | | 12.5% | 1.25 |
| Engineering | 71,931 | 102,177 | | 0.96 | 0.78 | 0.90 | 1.22 | 8.21 | | 12.3% | 1.29 |
| Information & Communication Technologies | 76,858 | 113,477 | | 1.08 | 0.73 | 0.92 | 1.44 | 8.82 | | 14.0% | 1.31 |
| **Arts & Humanities** | **27,508** | **31,520** | | **1.14** | **0.76** | **1.29** | **1.17** | **3.59** | | **12.1%** | **1.31** |
| Communication & Textual Studies | 10,803 | 12,080 | | 1.18 | 0.75 | 1.26 | 1.23 | 3.28 | | 12.7% | 1.30 |
| Historical Studies | 7,571 | 9,241 | | 1.10 | 0.73 | 1.07 | 1.13 | 3.97 | | 11.9% | 1.43 |
| Philosophy & Theology | 7,367 | 8,288 | | 1.13 | 0.79 | 1.56 | 1.13 | 4.04 | | 11.7% | 1.22 |
| Visual & Performing Arts | 1,767 | 1,911 | | 1.04 | 0.90 | 1.84 | 1.10 | 1.78 | | 10.8% | 1.19 |
| **Economic & Social Sciences** | **69,533** | **91,416** | | **1.16** | **0.80** | **1.31** | **1.03** | **2.14** | | **10.2%** | **1.15** |
| Economics & Business | 24,939 | 37,230 | | 1.25 | 0.82 | 1.13 | 1.04 | 2.41 | | 10.4% | 1.23 |
| Social Sciences | 44,594 | 54,186 | | 1.20 | 0.81 | 1.44 | 1.03 | 2.00 | | 10.1% | 1.10 |
| **Health Sciences** | **322,229** | **496,383** | | **1.15** | **0.88** | **1.26** | **1.18** | **6.01** | | **12.1%** | **1.36** |
| Biomedical Research | 54,576 | 88,131 | | 1.03 | 0.76 | 1.12 | 1.05 | 2.73 | | 10.6% | 1.21 |
| Clinical Medicine | 191,825 | 304,067 | | 1.16 | 0.89 | 1.12 | 1.24 | 7.91 | | 13.0% | 1.48 |
| Psychology & Cognitive Sciences | 30,179 | 42,551 | | 1.15 | 0.87 | 2.04 | 1.04 | 2.05 | | 9.8% | 1.12 |
| Public Health & Health Services | 45,649 | 61,634 | | 1.31 | 0.94 | 2.14 | 1.14 | 4.29 | | 11.5% | 1.10 |
| **Natural Sciences** | **150,288** | **254,411** | | **1.01** | **0.77** | **0.76** | **1.12** | **4.63** | | **11.1%** | **1.27** |
| Biology | 30,194 | 50,551 | | 1.01 | 0.75 | 1.05 | 1.16 | 7.04 | | 12.0% | 1.37 |
| Chemistry | 29,241 | 43,440 | | 0.98 | 0.77 | 0.59 | 1.11 | 4.73 | | 11.1% | 1.25 |
| Earth & Environmental Sciences | 32,138 | 56,924 | | 1.16 | 0.71 | 1.05 | 1.05 | 3.51 | | 9.8% | 1.29 |
| Mathematics & Statistics | 14,908 | 23,973 | | 1.07 | 0.83 | 0.80 | 1.11 | 1.24 | | 9.5% | 1.12 |
| Physics & Astronomy | 43,807 | 79,523 | | 0.93 | 0.75 | 0.61 | 1.16 | 4.75 | | 12.1% | 1.24 |

Note: n.c.: not calculated. The scale in the trends is not the same across domains and fields of research.
Impact indicators (ARC, CDI, HCP10, FWCS, and CDI) are not calculated for groups with fewer than 30 papers that have a relative citation (RC) score. Only papers published in 2021 or earlier have an RC score. Indicators were normalized by field and year and against the world level. Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure).

Source: Computed by Science-Metrix using data from Scopus

Canada has increased its output over the period in all domains and fields (GR > 1) except for three fields which had a GR just below 1: Chemistry (GR = 0.93), Engineering (GR = 0.96), and Physics & Astronomy (GR = 0.93). The largest growth in output occurred in the fields of Public Health & Health Services (GR = 1.31), Built Environment & Design (GR = 1.26), and Economics & Business (GR = 1.25). The growth in these fields may be due to an increase in publications in these fields in response to the COVID-19 pandemic. Despite some of these large increases, the growth in all fields was below the world level (GI < 1).

Canada is highly specialized in many fields of science (SI > 1), especially in Public Health & Health Services (SI = 2.14), Psychology & Cognitive Sciences (SI = 2.04), and Visual & Performing Arts (SI = 1.84). Areas where Canada is not specialized include fields in the Natural Sciences (particularly in the fields of Chemistry, Physics & Astronomy, and Mathematics & Statistics) and in the Applied Sciences (particularly Enabling & Strategic Technologies, Engineering, and Information & Communication Technologies).

Canada's strong impact in all domains and fields of science is undeniable. The ARC scores in Applied Sciences (1.25), Health Science (1.18), Arts & Humanities (1.17), and Natural Sciences (1.12) were all well above the world level while the ARC for Economic & Social Sciences (1.03) was just above the world level. At the field level, Information & Communication Technologies stands apart from all other fields with an ARC of 1.44. Three of the five fields that had an ARC score in the range of 1.20–1.24 were also in the Applied Science domain (Agriculture, Fisheries & Forestry, Engineering, and Enabling & Strategic Technologies). Fields with an ARC below 1.10 were Social Sciences (1.03), Psychology & Cognitive Sciences (1.04), Economics & Business (1.04), Earth & Environmental Sciences (1.05), Biomedical Research (1.05), and Build Environment & Design (1.06). The analysis of the highly cited papers indicator ($HCP_{10\%}$) results in a similar conclusion: Canada has a larger share of its publications in the top 10 most cited papers compared to the global average in nearly all fields. Mathematics & Statistics had the lowest $HCP_{10\%}$, at 9.5%, while Psychology & Cognitive Sciences, Earth & Environmental Sciences, and Built Environment & Design all had $HCP_{10\%}$ just below 10% (9.8%). Fields in which publications highly exceeded the expected 10% include Clinical Medicine ($HCP_{10\%}$ = 13%) and Information & Communication Technologies ($HCP_{10\%}$ = 14.0%). These findings coincide well with the CDI scores and CDC distribution across fields as well as the FWSC values above 1, which reflect the fact that Canadian researchers generally publish in influential journals.

Figure 1 depicts a positional analysis of Canada's impact, specialization and growth in each field of science. ARC is plotted along the y-axis while the SI is plotted along the x-axis. The GR is represented by the colour of the bubbles. The size of the bubbles is proportional to number of publications. This figure provides a clear overview of Canada's research portfolio at a glance and has the potential to support the identification of strategic fields depending on the policy questions that need to be addressed. In particular, it can be used to identify Canada's scientific strengths or areas that could be improved. For example, the fields of Physics & Astronomy, Chemistry, and Engineering are underrepresented as part of total output (low SI and low GR). All fields in the upper right quadrant of Figure 1 are fields where Canada is outperforming the world in terms of both specialization and impact. In this regard, no field stands out as an area of both high specialization and high impact. Canada is highly specialized and has seen high growth in the field of Public Health & Health Services, although its impact could be improved.

Research in Information & Communication Technologies also stands out for its very high impact and relatively high growth and could represent an area of further specialization in the future to strengthen Canada's position in this field as a leader.

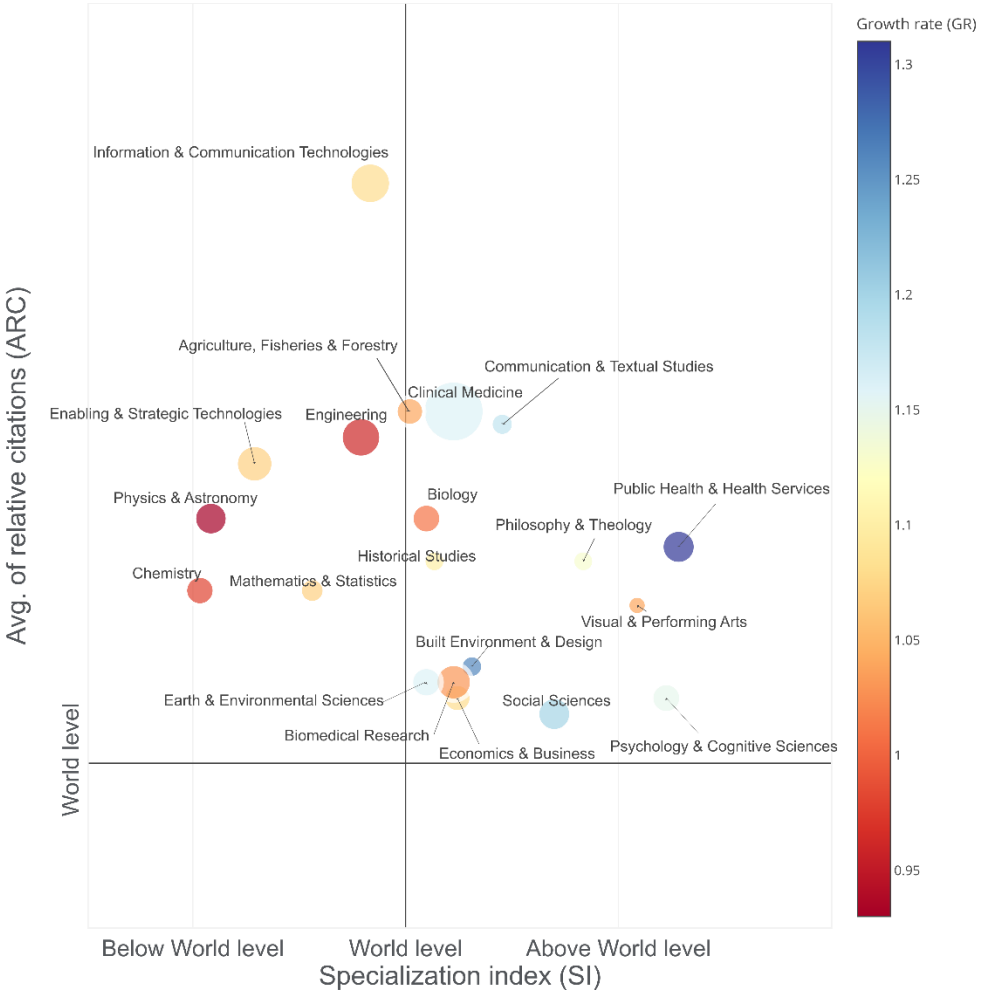


Figure 1 Positional analysis of Canada for the fields of science (2012–2023)

Note: The size of the bubbles is proportional to the number of publications (fractional counting). The SI and ARC are log-transformed to increase readability.

Source: Computed by Science-Metrix using data from Scopus

### 2.2.4 Emerging subfields

Emerging subfields are identified as those whose growth relative to Canada is greater than their growth relative to the world ($GR_{Canada} > GR_{World}$) and where Canada is performing well in terms of its impact (at least above world level). Figure 2 depicts a selection of 14 such subfields that are growing in Canada at a higher rate than the world output (reflected by all subfields being above the diagonal line in Figure 2). Eleven of the fourteen subfields are within the Health Sciences domain, while a single subfield represents each of the domains of Natural Sciences (Ornithology), Economic & Social Sciences (Family Studies), and Arts and Humanities (Folklore). Canada has no emerging subfield in Applied Sciences. Canada's most strongly emerging subfield is Substance Abuse ($GR_{Canada} = 1.89$; $GR_{World} = 1.38$). This subfield stands out because of the particularly high GR in Canada compared with the world as well as because it is one of

only four subfields that persists as an emerging subfield since the previous report (*Bibliometrics analysis for the Expert Panel on the State of Science & Technology in Canada 2016*). The newly emerging subfields of Folklore ($GR_{Canada}$ = 1.82; $GR_{World}$ = 1.46) and General Psychology & Cognitive Science, stand apart for their high GR in Canada compared with the world ($GR_{Canada}$ = 1.21; $GR_{World}$ = 1.03). Only a single subfield, that of Ornithology, had a growth ratio below 1 ($GR_{Canada}$ = 0.96; $GR_{World}$ = 0.83), indicating a decrease in output in Canada, but at a smaller rate than what is observed at the world level.

Note that of the 28 subfields identified in the previous report, only 27 are still covered in the present classification.[10] Of these 27 subfields, only 4 persisted as emerging subfields in the present report. Along with Substance Abuse, mentioned above, Dermatology & Venereal Diseases, Emergency & Critical Care Medicine, and Environmental & Occupational Health were identified as emerging subfields previously as well. Of the remaining 23 subfields, Canada maintains a high citation-based impact (i.e., surpasses the world level) for 20 of these. However, growth of these subfields in Canada failed to surpass the world growth rate, which was why they did not persist as emerging subfields. For example, in the 2016 report, Anatomy and Morphology was singled out as a very promising subfield in Canada's scientific landscape because its output grew substantially over the study period of 2003–2014 ($GR_{Canada}$ = 1.61; $GR_{World}$ = 1.41) while its impact was very high. However, over the study period of 2012–2023, $GR_{Canada}$ was less than $GR_{world}$ ($GR_{Canada}$ = 1.14; $GR_{World}$ = 1.26) although impact remains very high (ARC = 1.60; HCP10% = 19.5%). An exception to this was Medical Informatics, which had significant decline in rank relative to the previous report due to a decline in citation-based indicators.

[10] General Science & Technology, which was identified in the last report, is a multidisciplinary subfield which is now reclassified at paper level.

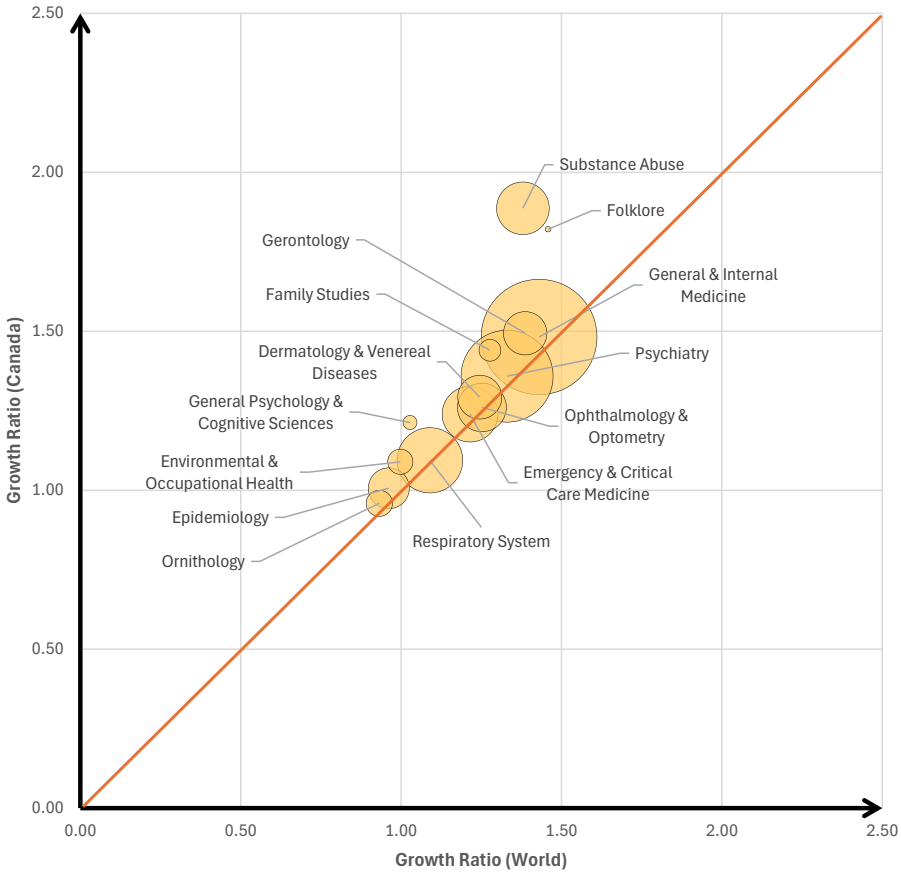


Figure 2 Positional analysis of a selection of 14 emerging subfields in Canada (2012–2023)

Note: The size of the bubbles is proportional to the number of publications (full counting).
Source: Computed by Science-Metrix using data from Scopus

In addition to Folklore and General Psychology & Cognitive Science, 8 new subfields not previously identified as emerging subfields were identified in the present analysis (Table VI). Table VI quantifies Canada's scientific performance in the 14 emerging subfields along with metrics related to scientific output, scientific impact and rank relative to the top 20 countries according to the composite indicator.

Table VI Canada's scientific performance in 14 emerging subfields (2012–2023)

| Field | Subfield | Scientific output | | | | | Scientific impact | | | Canada's ranking (composite) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FULL | FRAC | GR | GI | SI | ARC | HCP10% | FWCS | 2000–2011 | 2012–2023 |
| Biology | Ornithology | 1,344 | 883 | 0.96 | 1.03 | 2.38 | 1.48 | 17.7% | 1.21 | 4 | 1 |
| Public Health & Health Services | **Substance Abuse** | 5,440 | 3,970 | 1.89 | 1.37 | 2.72 | 1.07 | 12.0% | 1.05 | 4 | 2 |
| Public Health & Health Services | Gerontology | 3,692 | 2,858 | 1.49 | 1.08 | 2.42 | 1.02 | 8.9% | 0.99 | 4 | 4 |
| Clinical Medicine | Respiratory System | 8,451 | 5,158 | 1.09 | 1.00 | 1.52 | 1.32 | 14.1% | 1.54 | 2 | 4 |
| Clinical Medicine | General & Internal Medicine | 26,308 | 17,190 | 1.48 | 1.04 | 1.07 | 1.78 | 19.7% | 2.35 | 2 | 3 |
| Public Health & Health Services | Epidemiology | 3,317 | 1,963 | 1.01 | 1.05 | 2.05 | 1.08 | 10.4% | 1.13 | 3 | 5 |
| Clinical Medicine | Psychiatry | 16,635 | 10,648 | 1.36 | 1.02 | 1.85 | 1.12 | 11.1% | 1.27 | 6 | 7 |
| Clinical Medicine | **Emergency & Critical Care Medicine** | 6,149 | 4,124 | 1.24 | 1.02 | 1.80 | 1.23 | 12.5% | 1.41 | 5 | 6 |
| Clinical Medicine | **Dermatology & Venereal Diseases** | 3,808 | 2,327 | 1.29 | 1.04 | 0.69 | 1.30 | 12.9% | 1.35 | 7 | 10 |
| Clinical Medicine | **Environmental & Occupational Health** | 1,248 | 907 | 1.09 | 1.09 | 1.18 | 1.29 | 13.2% | 1.43 | 5 | 7 |
| Clinical Medicine | Ophthalmology & Optometry | 4,671 | 3,197 | 1.26 | 1.01 | 0.77 | 1.02 | 9.0% | 1.25 | 8 | 6 |
| Social Sciences | Family Studies | 937 | 703 | 1.44 | 1.13 | 1.71 | 1.04 | 10.9% | 1.07 | 6 | 7 |
| Psychology & Cognitive Sciences | General Psychology & Cognitive Sciences | 389 | 279 | 1.21 | 1.18 | 0.80 | 1.17 | 11.3% | 1.32 | 6 | 11 |
| Visual & Performing Arts | Folklore | 61 | 54 | 1.82 | 1.25 | 0.49 | 2.32 | 23.7% | 1.77 | 1 | 6 |

Note: Composite ranking corresponds to Canada ranking among the 20 most publishing countries based on its composite indicator scores. Colour coding indicates performances above (green), on par with (white) or below (red) the world level, except for the GR where it corresponds to growth (green is higher than 1). The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Emerging subfields that are returning from the previous report are bolded.

Source: Computed by Science-Metrix using data from Scopus

The majority of Canada's emerging subfields represent areas of high specialization. Substance abuse, Ornithology, Gerontology, and Epidemiology all had SI > 2. The emerging subfields where Canada is not specialized compared to the global standard were Folklore, Dermatology & Venereal Disease, Ophthalmology & Optometry, and General Psychology & Cognitive Sciences.

Compared to the top countries, it is somewhat paradoxical that Canada is either stable or losing ground in most of its emerging subfields. For instance, between the periods 2000–2011 and 2012–2023, Canada's rank based on composite indicator score decreased by at least one position in 10 of the 14 emerging subfields. Folklore and General Psychology & Cognitive Sciences had the biggest decline in rank, with both declining by 5 positions. General Psychology & Cognitive Sciences is of particular interest, given that it was identified as an emerging area in the previous report. In many cases, these are the result of countries emerging with larger levels of output and growth. Canada continued to increase in rank in Substance Abuse, where Canada has had a very high GR relative to the world GR and moved from 4th place based on 2000–2011 metrics to 2nd position based on 2012–2023 metrics. In addition, Canada increased in rank in Ornithology and Ophthalmology & Optometry.

### 2.2.5 Publishing behaviour of different sectors

Author affiliations on scientific publications have been classified in four different sectors—academic, government, medical and private corporations[11]—to analyze their publication behaviour. The academic sector includes all universities and colleges. The medical sector includes all hospitals, clinics and healthcare-providing institutions, including university hospitals. The private sector is composed of profit-driven corporations, including their research centres. Figure 3 presents the publishing behaviour of those four sectors.

[11] Not-for-profit sector is not explicitly shown as a separate sector since 98% of not-for-profit sector publications are covered by the Academic Sector in Canada.

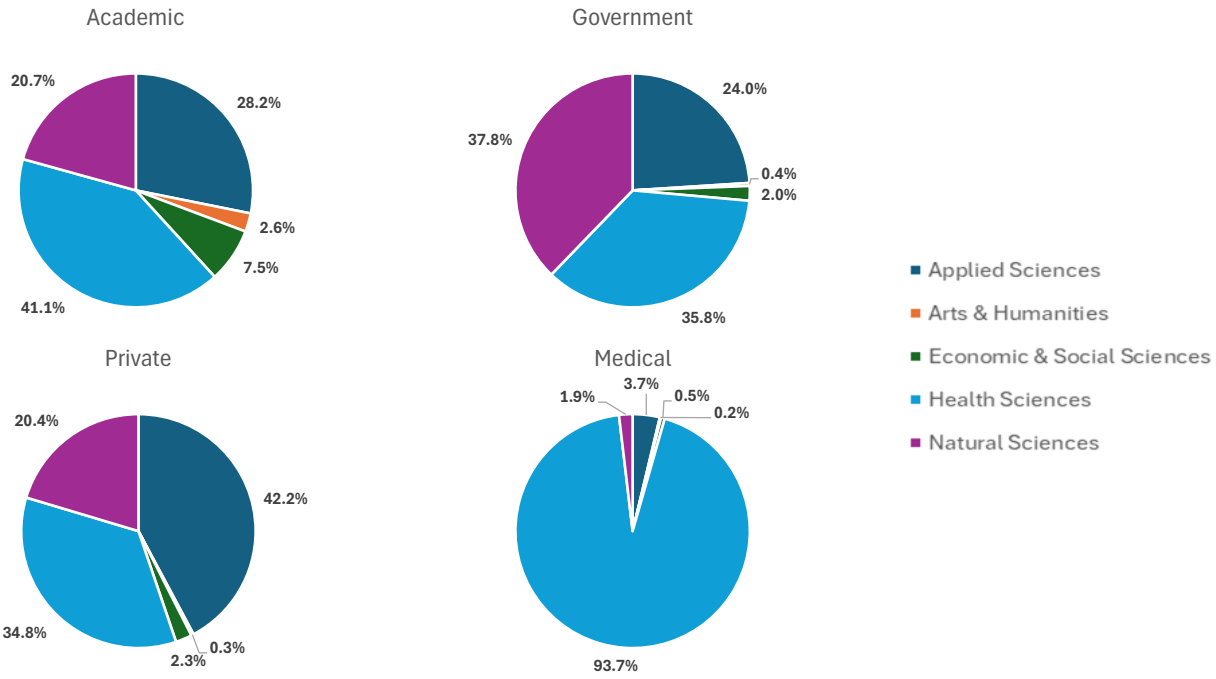


Figure 3 Proportion of publications by domains and sectors (2012–2023)
Source: Computed by Science-Metrix using Scopus (Elsevier)

The academic sector published most of its articles in Health Sciences (41.1%), Applied Sciences (28.2%) and Natural Sciences (20.7%) journals. A small proportion of its publications are published in Economic & Social Sciences (7.5%), and Arts & Humanities (2.6%) journals. The medical sector unsurprisingly publishes the vast majority (93.7%) of its articles in Health Sciences journals. Nevertheless, a few of its publications are published in Applied Sciences (3.7%) and Natural Sciences (1.9%) journals.

Government agencies mostly publish in Natural Sciences (37.8%), Health Sciences (35.8%) and Applied Sciences (24.0%), with a smaller output in Economic & Social Sciences (2.0%) and a negligible output in Arts & Humanities (0.4%). The private sector closely mimics the output of the government sector with the exception that it publishes a larger fraction of its papers in Applied Sciences (42.2%). This is not surprising since the corporations that publish most are engineering and telecommunication companies, for instance Hydro-Québec, SNC Lavalin (now AtkinsRéalis), WSP Global and FPInnovations. Companies also publish in Health Sciences (34.8%) and Natural Sciences (20.4%). As in the government sector, the private sector had a modest output in the domain of Economic & Social Sciences (2.3%) and a negligible output in the Arts & Humanities domain (0.3%).

## 2.3 Cluster-based identification of Canada's strengths in highly interdisciplinary fields

To complement and build on the analyses presented above, which are based on more traditional journal-based classifications of science, the classification of research output into research "topics" created via

direct citation analysis of publications[12] provides a different perspective on areas of more granular strength and is particularly valuable in the identification of interdisciplinary topics.

To identify the topic clusters that are interdisciplinary, Science-Metrix computed the DDR of each of their respective papers based on the distribution of all references listed in each paper across the subfields (or disciplines) of the traditional journal-based classification used in this study. The clusters that scored the highest average DDR scores for the 2018–2023 period were deemed to be the most interdisciplinary. The threshold for the identification of the most interdisciplinary clusters was selected after an analysis of the distribution of scores across the close to 1500 clusters, identifying a natural break at a DDR score of 1.25. The 115 clusters with a DDR score at or above 1.25 at the world level were retained as potential candidates for this analysis. It should be noted that when a paper only has one reference indexed in Scopus, its interdisciplinary score is always equal to 0, which means that it is impossible to detect interdisciplinarity for these papers. The number of references listed on papers improves the chance of detecting increases in interdisciplinarity; thus, areas in which researchers are known to list few references in their papers are less likely to come out as being interdisciplinary in this analysis. This likely explains why many of the topics retained as strengths for Canada are in the health sector. This is also a limitation in disciplines where citations are low, such as social sciences and the humanities, as it is more difficult to detect interdisciplinarity in these cases. Nevertheless, the topics that were identified as being interdisciplinary are not less so because of these limitations. Clusters were only selected as strengths for Canada if the ARC and FWCS for Canada's papers within the cluster surpassed the world average by 10%, and if Canada presented with a fractional count of publications of at least 100. Science-Metrix identified 37 interdisciplinary research topics in which Canada has strengths (Table VII).

[12] For methodology, see https://www.elsevier.com/products/scival/overview/topics#2-methodology

## Table VII Selection of highly interdisciplinary topic clusters where Canada exhibits strength (2018–2023)

| Cluster | Cluster Keywords | Scientific output | | | | | Scientific impact | | | Composite rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | | FULL | FRAC | GR | GI | SI | ARC | HCP10% | FWCS | 2018–2023 |
| 148 | Randomized Controlled Trial; Quality of Life; Anxiety Disorder | 1,521 | 996 | 1.20 | 0.99 | 2.21 | 1.09 | 9.6% | 1.13 | 12 |
| 603 | Quality of Life; Survivorship in Cancer Care; Oncology | 1,048 | 748 | 1.07 | 0.85 | 2.58 | 0.97 | 10.3% | 1.04 | 4 |
| 1507 | Alaska; Climate Change; Canada | 742 | 642 | 0.95 | 0.96 | 15.07 | 0.94 | 7.6% | 1.12 | 1 |
| 127 | Rock Mechanics; Ultimate Tensile Strength; Crack Propagation | 975 | 588 | 0.66 | 0.58 | 0.85 | 1.23 | 12.6% | 1.11 | 5 |
| 251 | Atmospheric Aerosol; Particular Matter 2.5; Environmental Monitoring | 996 | 552 | 0.98 | 0.76 | 1.01 | 1.62 | 19.8% | 1.69 | 11 |
| 443 | Ultrasonics; Medical Ultrasound; Signal-to-Noise Ratio | 692 | 528 | 0.82 | 0.83 | 1.74 | 0.97 | 8.4% | 1.14 | 8 |
| 1114 | Health Service; Discrimination; Quality of Life | 549 | 458 | 1.22 | 0.93 | 3.03 | 1.11 | 10.3% | 1.04 | 4 |
| 1033 | Food Waste; Agricultural Science; Supply Chain Management | 573 | 425 | 1.51 | 0.96 | 1.60 | 2.22 | 21.1% | 1.31 | 7 |
| 833 | Pro-Environmental Behavior; Climate Change; Environmental Policy | 514 | 360 | 1.53 | 0.97 | 1.04 | 1.92 | 21.1% | 1.32 | 14 |
| 398 | Uranium; Radon; Gamma Spectroscopy | 488 | 350 | 0.85 | 0.83 | 1.14 | 0.73 | 3.7% | 1.03 | 14 |
| 751 | Mathematical Modeling; Periodic Solution; Optimal Control Theory | 655 | 332 | 0.88 | 0.75 | 1.13 | 1.37 | 15.1% | 1.06 | 17 |
| 467 | Reliability Analysis; Engineering; Condition-Based Maintenance | 484 | 315 | 1.01 | 0.87 | 0.83 | 1.89 | 21.5% | 1.22 | 5 |
| 1319 | Kriging; Geostatistics; Interpolation | 393 | 293 | 0.94 | 0.88 | 2.43 | 1.09 | 10.1% | 1.12 | 4 |
| 589 | Data Envelopment Analysis; Industry; Regression Analysis | 524 | 293 | 0.79 | 0.65 | 0.89 | 1.44 | 20.7% | 1.53 | 4 |
| 787 | Computed Tomography; Finite Element Method; Osteoporosis | 454 | 277 | 0.77 | 0.70 | 1.29 | 1.20 | 11.9% | 1.42 | 19 |
| 762 | Internet of Things; Network Security; Cloud Computing | 427 | 276 | 1.30 | 0.96 | 0.54 | 2.02 | 23.4% | 1.30 | 17 |
| 681 | User Experience; User-Centered Design; Human-Computer Interaction | 360 | 273 | 0.93 | 0.94 | 1.07 | 1.39 | 15.1% | 0.86 | 11 |
| 520 | Drug Delivery System; DNA; RNA | 398 | 256 | 1.44 | 1.24 | 1.04 | 1.65 | 17.4% | 1.51 | 6 |
| 758 | Informed Consent; Clinical Trial; Biomedical Research | 364 | 255 | 1.10 | 1.00 | 1.66 | 0.72 | 6.0% | 1.21 | 12 |
| 736 | Global Positioning System; Radio Navigation; Antenna | 344 | 235 | 0.81 | 0.76 | 0.78 | 1.20 | 16.6% | 1.06 | 5 |
| 976 | Terahertz Spectroscopy; Antenna; Laser Pulse | 303 | 230 | 1.46 | 1.39 | 1.18 | 1.14 | 12.5% | 1.35 | 8 |
| 897 | Forestry; Fourier Transform Infrared Spectroscopy; Scanning Electron Microscopy | 349 | 224 | 0.90 | 0.85 | 1.04 | 1.02 | 9.8% | 1.00 | 11 |
| 390 | Magnetic Resonance Imaging; Transmission Electron Microscopy; Iron Oxide | 352 | 218 | 0.77 | 0.74 | 0.62 | 2.98 | 8.9% | 1.67 | 4 |
| 1065 | Natural Resource; Environmental Policy; Deforestation | 377 | 210 | 0.97 | 0.89 | 1.28 | 1.01 | 10.4% | 1.25 | 16 |
| 530 | Kalman Filtering; Gaussian Distribution; Information Theory | 336 | 204 | 0.84 | 0.85 | 0.77 | 1.04 | 11.1% | 1.27 | 7 |
| 1398 | Road; Life Cycle Assessment; Pavement Design | 252 | 196 | 0.82 | 0.74 | 1.68 | 1.04 | 6.8% | 0.97 | 6 |
| 1223 | Inertial Navigation; Kalman Filtering; Microelectromechanical System | 245 | 174 | 0.56 | 0.60 | 1.10 | 1.12 | 9.3% | 1.26 | 5 |
| 558 | Vibration Analysis; Blind Signal Separation; Independent Component Analysis | 324 | 156 | 1.07 | 0.73 | 0.39 | 2.87 | 38.0% | 1.49 | 7 |
| 1038 | Petroleum Reservoir; Nuclear Magnetic Resonance; Finite Element Method | 248 | 155 | 0.92 | 0.98 | 0.78 | 1.18 | 6.3% | 0.98 | 6 |
| 540 | Near Infrared Spectroscopy; Hyperspectral Imaging; Chemometrics | 241 | 147 | 1.68 | 1.40 | 0.46 | 1.10 | 11.7% | 1.11 | 17 |
| 1258 | Fluorine; Radiochemistry; Bremsstrahlung | 273 | 137 | 1.08 | 1.08 | 1.47 | 1.23 | 16.0% | 1.22 | 2 |
| 537 | Electric Discharge; Control Flow; Plasma Application | 200 | 127 | 1.66 | 1.58 | 0.44 | 1.06 | 10.1% | 1.23 | 29 |
| 1030 | Temporomandibular Joint; Masticatory Muscle; Thermography | 231 | 124 | 1.23 | 0.99 | 0.71 | 0.98 | 8.9% | 1.14 | 18 |
| 1214 | e-Government; Open Data; Social Media | 154 | 115 | 1.05 | 0.90 | 0.74 | 2.12 | 14.6% | 1.30 | 10 |
| 1440 | Russia; Industry; Arctic Region | 151 | 110 | 0.83 | 0.93 | 0.99 | 0.98 | 14.6% | 0.99 | 6 |
| 1283 | Calcite; Biomineralization; Scanning Electron Microscopy | 182 | 109 | 0.71 | 0.65 | 0.82 | 1.37 | 14.4% | 1.47 | 5 |
| 1254 | Internet of Things; Information System; Artificial Intelligence | 161 | 108 | 1.01 | 0.85 | 0.54 | 1.56 | 18.5% | 1.24 | 21 |

Note: Composite ranking corresponds to Canada ranking among the 20 most publishing countries based on its composite indicator scores. Clusters are first selected for their high DDR at world level. To be of strength for Canada, the ARC and the FWCS must be 10% higher than the World average - . Impact indicators (ARC, HCP10, FWCS) are not calculated for groups with fewer than 30 papers that have a relative citation (RC) score. Only papers published in 2021 or earlier have an RC score. Indicators were normalized by subfield and year and against the world level. At topic clusters level, the scores of the world differ from what is expected at subfield level (ARC and FWCS do not equal 1; HCP10 does not equal 10%). Colour coding indicates scores below (red) or above (green) the normalized score of the world in fields of science. The gradient represents the level of departure from the world normalized value. As relative citation scores are not normalized by topics, the score of the world is not 1 (for ARC and FWCS) or 10% (for HCP10).

Source: Computed by Science-Metrix using Scopus (Elsevier)

Applied Sciences were the most highly represented domain among the topic clusters with 19 of the 37 clusters falling mainly within this domain. All five fields of Applied Sciences were represented among the clusters, providing insight into the highly interdisciplinary nature of the Applied Sciences in Canada. This represents a major shift since the previous report (covering the period 2003–2014), in which Applied Sciences had a very low representation among the interdisciplinary topics.[13] Applied Sciences-related topics also had the highest levels of impact: Magnetic Nanoparticles in Environmental Applications (ARC = 2.98, $HCP_{10\%}$ = 9%), Enhancing Fault Diagnosis Methods (ARC = 2.87, $HCP_{10\%}$ = 38%), Reducing Food Waste Impact (ARC = 2.22, $HCP_{10\%}$ = 21%), Innovating IoT Applications (ARC = 2.02, $HCP_{10\%}$ = 23%), and Reliability and Maintenance Strategies (ARC = 1.89, $HCP_{10\%}$ = 22%).

Health Sciences and Natural Sciences had a similar representation among the topic clusters. Within Health Sciences, 6 of the 8 topic clusters aligned most closely with the field of Clinical Medicine. Indeed, the topics that Canada had the highest count of publications in were within this domain: Chronic Pain Management (1,000 articles by fractional counting) and Cancer Care Impact (750 articles). Canada was highly specialized in these topics (Chronic Pain Management SI = 2.21; Cancer Care Impact SI = 2.58). However, the growth index and scientific impact in both topics was moderate. The highest impact topics that were related to Health Sciences were Enhancing Gene Therapy (ARC = 1.65; $HCP_{10\%}$ = 17%), and Air Pollution Impact Assessment (ARC = 1.62; $HCP_{10\%}$ = 20%).

Within Natural Sciences, the topic clusters aligned most closely with the fields of Earth & Environmental Sciences and Physics & Astronomy. Ultrasound Imaging Advancements, which aligns with the field of Physics & Astronomy, stands out as an area that Canada is highly specialized in (SI = 1.74).

The topic that had the highest rank based on Composite Indicator Score was Inuit Population and Culture, a topic that Canada is extremely specialized in (640 articles; SI = 15.07). Despite this, the ARC, $HCP_{10\%}$ and GR for Canada's publications in this topic were below the world average. In contrast, the topic of Nuclear Reaction Modeling, which had the 2nd highest rank based on Composite Indicator Score, had a high scientific impact (ARC = 1.23; $HCP_{10\%}$ = 16.0%). However, Canada's growth in this topic was modest (GR = 1.08) as was its publication output (140 articles).

## 2.4 Scientific performance of Canada's leading institutions

This section explores the scientific production and impact of Canada's most publishing institutions. Table VIII lists the top 45 institutions according to their fractional output between 2012 and 2023. The University of Toronto tops the list with 100,000 publications (12.4% of Canada's total output), well ahead of its nearest competitor, the University of British Columbia (57,000 publications; 7.0%). McGill University ranks 3rd with 46,000 publications (5.7%), followed by the University of Alberta (45,000 publications; 5.6%) and the University of Montreal (36,000 publications; 4.4%) in 5th place. The list is mostly composed of universities with a few government agencies included. The top publishing government agencies include the National Research Council (27th place; 6,300 publications; 0.8%),

[13] Since the last report, additional normalization have been implemented to the indicators on interdisciplinarity, which better control for differences across disciplines and could explain the more diverse set of clusters included.

Agriculture and Agri-Food Canada (28th place; 5,900 publications; 1.1%) and the Institut National de la Recherche Scientifique (31st place; 5,000 publications; 0.8%).

Most Canadian institutions increased their publication output between 2012–2017 and 2018–2023 (Table VIII). Lakehead University increased its output by almost 40% (GR = 1.37), the only Canadian institution with growth on par with the world level (GI = 1.00). École de Technologie Supérieure ranked 2nd in growth (GR = 1.34), followed by Université du Québec à Trois-Rivières (GR = 1.28), Ontario Tech University (GR = 1.22) and Brock University (GR = 1.22). The largest GR within the top 25 is observed from University of Guelph (GR = 1.21), the Memorial University of Newfoundland (GR = 1.20) and York University (GR = 1.19). The institutions that reduced publication output between both periods, albeit at a low rate, are almost all agencies from the federal government, a continued trend from the previous report: the Agriculture and Agri-Food Canada (GR = 0.79), Environment and Climate Change Canada (GR = 0.90), Natural Resources Canada (GR = 0.92) and National Research Council (GR = 0.94). The University of Victoria (GR = 0.94), Trent University (GR = 0.96), Université Laurentienne (GR = 0.98), and Simon Fraser University (GR = 0.98) are the only universities among the most publishing with a decreasing level of publications.

## Table VIII Scientific performance of Canada's leading institutions (2012–2023)

| Institution | Scientific output | | | | | Scientific impact | | | | | Collaboration | | Cross-disciplinary | | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FRAC* | FULL | Trend (FRAC) | GR* (FRAC) | GI (FRAC) | ARC* | CDI | CDC | $HCP_{10\%}$* | FWCS | ICR | PPP | DDR10* | DDA10* | Score | Rank |
| University of Toronto | 100,395 | 199,026 | | 1.12 | 0.82 | 1.34 | 9.1 | | 14.3% | 1.51 | 54.4% | 8.4% | 8.7% | 10.9% | 0.49 | 1 |
| The University of British Columbia | 57,250 | 121,002 | | 1.07 | 0.78 | 1.32 | 9.3 | | 14.4% | 1.46 | 57.4% | 8.0% | 9.8% | 11.9% | 0.34 | 16 |
| McGill University | 46,485 | 98,538 | | 1.03 | 0.75 | 1.28 | 9.3 | | 14.1% | 1.46 | 56.5% | 7.3% | 9.2% | 12.5% | 0.34 | 17 |
| University of Alberta | 45,298 | 89,935 | | 1.12 | 0.82 | 1.17 | 7.1 | | 11.9% | 1.36 | 52.2% | 7.5% | 9.4% | 12.5% | 0.33 | 21 |
| Université de Montréal | 35,908 | 78,074 | | 1.08 | 0.79 | 1.11 | 4.7 | | 10.5% | 1.37 | 53.0% | 8.0% | 8.3% | 12.2% | 0.32 | 29 |
| University of Calgary | 33,063 | 67,791 | | 1.18 | 0.86 | 1.20 | 6.9 | | 12.0% | 1.36 | 50.6% | 8.0% | 9.7% | 12.6% | 0.36 | 9 |
| University of Ottawa | 30,454 | 62,704 | | 1.14 | 0.83 | 1.18 | 5.6 | | 11.6% | 1.34 | 47.7% | 6.2% | 9.4% | 12.4% | 0.34 | 14 |
| University of Waterloo | 29,071 | 53,586 | | 1.09 | 0.80 | 1.31 | 8.5 | | 13.9% | 1.32 | 53.1% | 8.3% | 10.3% | 11.6% | 0.40 | 2 |
| Western University | 28,211 | 53,683 | | 1.05 | 0.77 | 1.14 | 5.6 | | 11.4% | 1.35 | 47.7% | 6.7% | 9.5% | 11.7% | 0.36 | 12 |
| McMaster University | 27,626 | 59,697 | | 1.14 | 0.83 | 1.32 | 6.9 | | 13.1% | 1.45 | 52.4% | 8.3% | 8.7% | 12.3% | 0.37 | 8 |
| Université Laval | 20,947 | 42,536 | | 1.08 | 0.79 | 1.11 | 5.6 | | 11.0% | 1.35 | 47.4% | 7.6% | 9.1% | 12.5% | 0.35 | 13 |
| University of Manitoba | 17,607 | 36,053 | | 1.10 | 0.80 | 1.06 | 4.0 | | 10.6% | 1.26 | 48.5% | 6.9% | 9.0% | 13.0% | 0.37 | 7 |
| Queen's University | 17,297 | 34,718 | | 1.10 | 0.81 | 1.10 | 5.4 | | 11.1% | 1.32 | 47.2% | 7.0% | 8.6% | 10.8% | 0.36 | 11 |
| Dalhousie University | 16,215 | 35,073 | | 1.09 | 0.80 | 1.11 | 5.0 | | 11.5% | 1.28 | 48.9% | 6.6% | 10.5% | 13.1% | 0.38 | 3 |
| University of Saskatchewan | 16,128 | 31,923 | | 1.13 | 0.82 | 0.98 | 2.7 | | 8.7% | 1.20 | 50.3% | 7.1% | 11.6% | 14.1% | 0.36 | 10 |
| University of Guelph | 14,032 | 26,267 | | 1.21 | 0.88 | 1.16 | 6.8 | | 12.0% | 1.21 | 48.7% | 7.7% | 11.9% | 12.1% | 0.37 | 6 |
| Concordia University | 13,872 | 23,418 | | 1.18 | 0.87 | 1.14 | 6.7 | | 11.3% | 1.26 | 44.8% | 5.3% | 8.7% | 9.1% | 0.33 | 22 |
| Simon Fraser University | 13,100 | 28,056 | | 0.98 | 0.72 | 1.17 | 6.8 | | 12.0% | 1.44 | 54.7% | 7.0% | 11.5% | 11.7% | 0.38 | 4 |
| York University | 12,772 | 25,124 | | 1.19 | 0.87 | 1.11 | 3.0 | | 11.2% | 1.25 | 48.3% | 4.6% | 11.8% | 12.6% | 0.37 | 5 |
| Carleton University | 11,794 | 23,176 | | 1.18 | 0.86 | 1.06 | 3.4 | | 10.3% | 1.24 | 47.6% | 5.9% | 9.2% | 9.6% | 0.32 | 27 |
| University of Victoria | 10,400 | 23,544 | | 0.94 | 0.69 | 1.19 | 6.4 | | 12.5% | 1.31 | 57.8% | 5.3% | 8.4% | 10.7% | 0.34 | 15 |
| Memorial University of Newfoundland | 10,202 | 18,946 | | 1.20 | 0.88 | 1.05 | 3.8 | | 10.5% | 1.20 | 47.2% | 6.1% | 11.2% | 12.6% | 0.34 | 19 |
| Toronto Metropolitan University | 9,602 | 17,267 | | 1.18 | 0.86 | 1.16 | 6.2 | | 11.2% | 1.18 | 41.9% | 5.2% | 12.7% | 11.9% | 0.34 | 20 |
| Université de Sherbrooke | 9,440 | 19,407 | | 1.09 | 0.80 | 1.01 | 3.0 | | 9.2% | 1.28 | 45.4% | 7.3% | 8.5% | 14.0% | 0.32 | 28 |
| Université du Québec à Montréal | 7,798 | 16,559 | | 1.07 | 0.78 | 1.00 | 2.1 | | 10.1% | 1.19 | 45.8% | 3.4% | 9.6% | 13.1% | 0.31 | 36 |
| University of Windsor | 6,517 | 11,069 | | 1.09 | 0.80 | 1.02 | 3.9 | | 10.6% | 1.15 | 47.2% | 6.4% | 8.3% | 10.5% | 0.29 | 42 |
| National Research Council Canada | 6,246 | 14,761 | | 0.94 | 0.69 | 1.15 | 5.8 | | 11.5% | 1.27 | 49.5% | 10.1% | 8.1% | 13.1% | 0.31 | 33 |
| Agriculture and Agri-Food Canada | 5,886 | 13,200 | | 0.79 | 0.58 | 1.16 | 7.9 | | 11.8% | 1.24 | 49.9% | 8.5% | 6.3% | 8.6% | 0.29 | 41 |
| École de Technologie Supérieure | 5,263 | 9,493 | | 1.34 | 0.98 | 1.31 | 10.0 | | 13.8% | 1.19 | 47.0% | 11.3% | 8.7% | 11.4% | 0.34 | 18 |
| University of New Brunswick | 5,258 | 10,559 | | 1.05 | 0.77 | 1.00 | 1.5 | | 9.3% | 1.17 | 52.8% | 7.5% | 10.2% | 10.5% | 0.29 | 43 |
| Institut National de la Recherche Scientifique | 4,991 | 10,426 | | 0.91 | 0.66 | 1.17 | 8.0 | | 11.9% | 1.34 | 58.4% | 8.1% | 7.2% | 10.6% | 0.31 | 37 |
| Ontario Tech University | 4,723 | 8,052 | | 1.22 | 0.90 | 1.29 | 8.1 | | 14.1% | 1.16 | 43.2% | 6.1% | 9.9% | 9.8% | 0.33 | 26 |
| University of Regina | 4,375 | 8,670 | | 1.21 | 0.89 | 1.13 | 4.0 | | 10.2% | 1.15 | 53.3% | 5.8% | 10.6% | 12.1% | 0.31 | 34 |
| Natural Resources Canada | 4,236 | 9,864 | | 0.92 | 0.67 | 1.17 | 6.9 | | 11.5% | 1.33 | 46.6% | 11.4% | 5.8% | 8.8% | 0.29 | 44 |
| Brock University | 4,055 | 7,547 | | 1.22 | 0.89 | 0.96 | 2.8 | | 9.3% | 1.14 | 45.8% | 3.3% | 9.6% | 9.8% | 0.28 | 46 |
| Provincial Health Services Authority | 3,606 | 11,775 | | 0.95 | 0.69 | 1.28 | 5.3 | | 12.3% | 1.59 | 52.8% | 10.1% | 8.1% | 13.2% | 0.33 | 25 |
| Environment and Climate Change Canada | 3,495 | 9,486 | | 0.90 | 0.66 | 1.18 | 8.1 | | 11.9% | 1.34 | 51.8% | 11.8% | 5.5% | 8.2% | 0.28 | 45 |
| Lakehead University | 3,397 | 7,428 | | 1.37 | 1.00 | 1.09 | 3.9 | | 10.9% | 1.17 | 44.5% | 4.7% | 10.5% | 14.0% | 0.32 | 30 |
| Wilfrid Laurier University | 3,294 | 6,613 | | 1.10 | 0.81 | 1.00 | 3.0 | | 9.9% | 1.15 | 45.1% | 3.0% | 13.4% | 13.2% | 0.32 | 32 |
| University of Lethbridge | 2,716 | 4,983 | | 1.00 | 0.74 | 0.78 | -1.8 | | 6.3% | 1.10 | 45.7% | 3.8% | 10.8% | 10.8% | 0.26 | 50 |
| Université du Québec à Trois-Rivières | 2,709 | 5,487 | | 1.28 | 0.94 | 0.93 | 0.0 | | 8.5% | 1.06 | 41.4% | 4.0% | 10.9% | 14.9% | 0.30 | 40 |
| Université Laurentienne | 2,522 | 5,571 | | 0.98 | 0.71 | 0.89 | -1.7 | | 7.8% | 1.06 | 41.2% | 7.2% | 12.1% | 15.9% | 0.30 | 38 |
| Fisheries and Oceans Canada | 2,416 | 6,623 | | 1.06 | 0.77 | 0.99 | 4.8 | | 8.6% | 1.28 | 54.0% | 11.4% | 6.0% | 8.9% | 0.26 | 49 |
| Trent University | 2,178 | 4,187 | | 0.96 | 0.70 | 0.87 | 0.9 | | 7.4% | 1.21 | 40.6% | 5.6% | 11.7% | 10.4% | 0.27 | 48 |
| Université du Québec à Chicoutimi | 1,913 | 3,777 | | 1.21 | 0.89 | 1.13 | 7.2 | | 12.5% | 1.07 | 46.0% | 11.7% | 11.4% | 13.6% | 0.33 | 23 |

Note: The trend charts are not comparable between institutions. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease)

and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using Scopus (Elsevier)

The scientific impact of the vast majority of the top publishing institutions in Canada is marked and notable (Table VIII). Just seven institutions among the top 45 score below the world level (ARC = 1.00). All other institutions in the top 45 surpass the global standard. The most impactful institutions include the University of Toronto (ARC =1.34), McMaster University (ARC = 1.32), and the University of British Columbia (ARC = 1.32). The situation is similar when analyzing the $HCP_{10\%}$ as both metrics tend to correlate strongly at high levels of aggregation.

High impact institutions owe their high score in part to their frequent collaborations with international partners. More than half of publications from the University of Toronto, McMaster University and the University of British Columbia are written in collaboration with foreign authors (Table VIII). The highest ICR is measured for the Institut National de la Recherche Scientifique (ICR = 58.4%), followed by the University of Victoria (57.8%). Trent University collaborated least with international partners with an ICR score of 40.6%.

The composite indicator ranks the institutions among the top 45 quite differently compared to publication output. The University of Toronto and the University of Waterloo score 1st and 2nd place, respectively, due in part to their impact but mostly to their output, and higher DDA in the case of Waterloo. The 3rd place is occupied by Dalhousie University, boosted by its higher performance on cross-disciplinary indicators. Simon Fraser University follows, with high impact and high cross-disciplinary research. York University completes the top 5, again combining high impact and high cross-disciplinarity. It is important to note that the composite score is quite close at the top. With the exception of the University of Toronto with its score of 0.49, an outlier mostly because of the university's high level of output, 12 universities fall in the 0.35–0.40 range, and different weights in the composite could have resulted in notable changes. For instance, slightly decreasing the weights for cross-disciplinary indicators would have resulted in higher impact universities, such as UBC and McMaster, scoring much closer to the top.

## 2.5 Scientific performance of a selection of Canadian CMAs

This section explores the scientific production and impact of a selection of Canadian Census Metropolitan Areas (CMAs).[14] Table IX presents the selection according to their fractional output between 2012 and 2023. A more complete set of core cities is included in the accompanying databook. Toronto's CMA tops the list with 118,000 publications (14.6% of Canada's total output), slightly ahead of Montréal's CMA at 108,000 publications (13.3%). Vancouver (64,000 publications; 7.9%), Ottawa–Gatineau (51,000 publications; 6.3%) and Edmonton (44,000 publications; 5.4%) follow. The top 5 CMAs account for 47% of all of Canada's publications. In 6th and 7th positions with, respectively, 31,000 publications and 29,000 publications, Calgary and Kitchener–Cambridge–Waterloo present at an intermediate level among the selected CMAs. Winnipeg, Halifax, Québec and Saskatoon occupy the next positions with publication

[14] The top 7 largest CMAs according to population as of 2024 were selected, plus the largest one for provinces without a CMA in this original selection. This resulted in a list of 16 CMAs. Whitehorse and Yellowknife are not always displayed as they do not always present with measurable output.

counts in the 15,000–20,000 publications range. Moncton and Charlottetown complete the list among CMAs of provinces with about 1,400–1,600 publications. Although researchers from CMAs in Canadian territories published less content, Whitehorse and Yellowknife still exhibit notable research activity, with 176 publications and 160 publications respectively.

Given the relative importance of each of the selected CMAs in the output of their respective provinces, patterns presented at the provincial level often correlate quite strongly with those presented here. For instance, the strong performance in impact of British Columbia is apparent in the data for Vancouver's CMA, which present the third highest ARC (ARC = 1.29). However, it is Kitchener–Cambridge–Waterloo (ARC = 1.32) and Toronto (ARC = 1.31) which come 1st and 2nd for that metric, again in alignment with Ontario's strong impact. Calgary (ARC = 1.20) and Montréal (ARC =1.19) complete the top 5 with similar impact.

Stronger growth is often observed for entities with lower levels of output, as it is much easier to score highly on growth metrics when starting levels are lower. This is reflected in Whitehorse's growth, the highest among selected CMAs (GR = 1.35). Moncton ranks 2nd (GR = 1.32), followed by Québec's CMA (GR = 1.24). The strong growth measure for Québec's CMA is notable as it enabled the CMA to overtake three CMAs over the last decade, Québec ranking 11th in 2012 (1,025 publications), and reaching 8th position in 2023 (1,665 publications), overtaking in the process Winnipeg, Halifax and Saskatoon. Quebec's CMA appears to have consolidated its position as important research hub not only in the province of Québec but on the national scene as well.

In addition to Québec, among larger CMAs, Calgary also stands out with a high growth (GR = 1.20). Toronto, the leading CMA in terms of output, is in the middle (GR = 1.12, 7th). On the opposite end, Montréal (GR = 1.04) and Vancouver (GR = 1.04) present with the lowest growth rates, their output having grown by about 4% over the two 6-year periods. Overall, although all CMAs have seen increases in publication outputs, none has been able to keep up with the average growth rate at the world level, with Whitehorse coming the closest to achieving this feat (GI =0.99).

Governmental organizations account for 16.4% of all Canadian publications, but this percentage increases to around 70% for Whitehorse and Yellowknife, indicating high reliance on governmental structures to publish. Ottawa–Gatineau also stands out with a rate of 32.5%, unsurprising given the region is host to a large number of federal research organizations. Kitchener–Cambridge–Waterloo (13.1%), Calgary (14.4%) Toronto (15.6%) and Montréal (17.7%) are present with the lowest relative contributions from the government sector.

Co-publications between the public and private for-profit sector are often an indication of dynamic R&D ecosystems where knowledge flows from fundamental research into more concrete innovations. Yellowknife presents with the highest public–private partnership (PPP) rate at 18.6%, followed by Whitehorse at 15.9%. The fact that territories rank at the top on the metrics is not surprising as these partnerships often exist to address tangible challenges faced by a region, and territories, with their unique cultural identities and geographical remoteness, present with strong needs for local solutions. Among other CMAs, Calgary (PPP = 10.4%), Toronto (PPP = 10.2%), Vancouver (PPP = 10.1%) and Québec (PPP = 9.1%) present with the highest rates. It is important to note that CMAs specializing in research areas of applied sciences will tend to present with highest PPP rates, as research in these areas are often

much further in the R&D chain. Nevertheless, the PPP helps identify areas where this knowledge transfer across the full chain is more prominent, potentially leading to news techniques and products, which is the focus of the next section of this report.

## Table IX Scientific performance of a selection of Canadian CMAs (2012–2023)

| Entity | Scientific output | | | | | Scientific impact | | | Cross-disciplinarity | | Collaboration | | | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FRAC* | FULL | Trend (frac) | GR* (FRAC) | GI (FRAC) | ARC* | $HCP_{10\%}$* | FWCS | DDR10* | DDA10* | % Private | % Gov | PPP | Score | Rank |
| **World** | **34,147,501** | **34,147,501** | | **1.37** | **1.00** | **1.00** | **10.0%** | **1.00** | **10.0%** | **10.0%** | **8.0%** | **14.9%** | **6.3%** | - | - |
| **Canada** | **812,794** | **1,227,990** | | **1.09** | **0.80** | **1.17** | **11.8%** | **1.30** | **9.6%** | **10.9%** | **9.3%** | **16.4%** | **8.1%** | - | - |
| Toronto | 118,644 | 230,976 | | 1.12 | 0.82 | 1.31 | 13.7% | 1.46 | 9.2% | 11.0% | 11.6% | 15.6% | 10.2% | 0.665 | 1 |
| Montréal | 108,370 | 200,331 | | 1.04 | 0.76 | 1.19 | 12.3% | 1.38 | 8.6% | 11.5% | 9.7% | 17.7% | 9.0% | 0.577 | 3 |
| Vancouver | 64,228 | 130,419 | | 1.04 | 0.76 | 1.29 | 13.8% | 1.46 | 10.1% | 11.7% | 11.4% | 24.8% | 10.1% | 0.509 | 6 |
| Ottawa-Gatineau | 50,958 | 101,112 | | 1.11 | 0.81 | 1.15 | 11.1% | 1.30 | 9.2% | 11.6% | 9.8% | 32.5% | 8.7% | 0.402 | 13 |
| Edmonton | 44,266 | 86,246 | | 1.10 | 0.80 | 1.17 | 11.9% | 1.37 | 9.2% | 12.3% | 9.1% | 18.3% | 8.3% | 0.461 | 8 |
| Calgary | 31,023 | 64,006 | | 1.15 | 0.84 | 1.20 | 11.8% | 1.36 | 9.7% | 12.4% | 12.8% | 14.4% | 10.4% | 0.513 | 4 |
| Kitchener-Cambridge-Waterloo | 29,028 | 54,986 | | 1.09 | 0.80 | 1.32 | 14.2% | 1.33 | 10.1% | 11.2% | 9.5% | 13.1% | 8.9% | 0.591 | 2 |
| Winnipeg | 19,494 | 38,938 | | 1.08 | 0.79 | 1.05 | 10.3% | 1.26 | 9.0% | 12.9% | 8.8% | 23.3% | 8.2% | 0.415 | 12 |
| Halifax | 18,176 | 38,630 | | 1.08 | 0.79 | 1.08 | 10.9% | 1.28 | 10.3% | 12.5% | 7.8% | 22.8% | 7.5% | 0.467 | 7 |
| Québec | 17,485 | 36,744 | | 1.24 | 0.91 | 1.12 | 11.3% | 1.37 | 9.0% | 12.3% | 9.7% | 25.1% | 9.1% | 0.511 | 5 |
| Saskatoon | 15,671 | 31,141 | | 1.09 | 0.80 | 0.99 | 8.9% | 1.22 | 10.9% | 13.5% | 8.8% | 24.6% | 8.4% | 0.428 | 9 |
| Moncton | 1,619 | 3,504 | | 1.32 | 0.97 | 0.81 | 7.0% | 1.10 | 9.6% | 14.2% | 5.5% | 25.1% | 5.3% | 0.323 | 14 |
| Charlottetown | 1,402 | 3,175 | | 1.21 | 0.89 | 0.89 | 7.7% | 1.09 | 12.5% | 15.4% | 8.1% | 26.5% | 7.6% | 0.424 | 10 |
| Whitehorse | 177 | 664 | | 1.35 | 0.99 | 0.92 | 7.5% | 1.26 | 8.3% | 10.5% | 17.5% | 65.5% | 15.9% | 0.279 | 15 |
| Yellowknife | 160 | 707 | | 1.13 | 0.83 | 1.09 | 10.7% | 1.27 | 8.0% | 14.5% | 19.7% | 72.3% | 18.6% | 0.417 | 11 |

Note: The trend charts are not comparable between CMAs. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.

Source: Computed by Science-Metrix using Scopus (Elsevier)

# 3 Technometrics

Technometrics are statistical analysis techniques based on patent applications and ownership data that provides insight into technological innovation of given entities. This section presents statistical indices for the leading countries, Canada and its provinces and territories in terms of their ownership of granted patents. In addition, data for cities and a selection of the largest Canadian Metropolitan Areas (CMA) are also provided, providing more insights into the location of innovation hubs in Canada. Patent data are collected from PatentsView and PATSTAT and pertain to those patents filed under the United States Patent and Trademark Office (USPTO) and the European Patent Office (EPO). The inclusion of the EPO data is a novelty in this report and aims at ensuring a more complete overview of the Canadian patenting ecosystem, and fairer comparisons as Canada typically presented with a net advantage over most countries when computing patent analysis solely on USPTO data, given its close proximity and strong economic ties with the US market. The following indicators are strictly based on the location of the original assignees (i.e., owners at the time the patents were granted) unless specified otherwise.

Section 3.1 evaluates the performance of the leading countries in the world, while Section 3.2 similarly analyzes the patenting behaviour of Canada's provinces and territories, and its cities according to their strongest technological fields. Lastly, Section 3.3 lists the top patenting institutions in Canada.

## 3.1 Technological performance of the world's leading countries

This section is devoted to the world's 20 leading countries based on their ownership of new patents filed at the USPTO between 2012–2023, and between 2011–2022 at the EPO.[15] Additional information on the performance of these countries that is not covered in this report is available in the accompanying Excel databook.

No single patent office covers all patents registered worldwide. However, since the US and EPO cover two of the largest markets globally, most economically important creations tend to be patented for these markets. Consequently, the USPTO and EPO act together as one the largest registries of patented inventions in the world and serve as a useful proxy for observing global trends for the purposes of this study.

### 3.1.1 Technological output and impact at the USPTO

Of the 3.7 million patents granted by the USPTO between 2012–2023, roughly half of them (49.7% of total based on fractional counting) are owned by US patentees (Table X). Japanese patentees own just over 600,000 patents (16.1% of total); therefore, US and Japanese entities possess more than 60% of the technological intellectual property (IP) filed with the USPTO. Though this is a high value, it represents a 10 percentage point decrease relative to the period 2003–2014 (*Bibliometrics analysis for the Expert Panel on the State of Science & Technology in Canada 2016*). With just under 240,000 patents (6.4% of total), South Korea now ranks 3rd. Germany, China, and Taiwan are 4th, 5th, and 6th, respectively, with 135,000–

[15] When this report was prepared, data for 2023 were still incomplete in the EPO database, leading to a shift of one year for analyses relying on these data.

180,000 patents each (3.7–4.8% of total). Canada ranks in 8th place with a total of 58,000 patents (1.6%), right below France, and above the United Kingdom by 5,000 patents. The ranking with respect to full counting is identical to the ranking based on fractional counting since the vast majority of patents are filed by a single assignee. For European countries, it is likely that they have prioritized the European Patent Office for the filing of patent protection before doing so with the USPTO, and therefore it is important to note that these figures are unlikely to represent any country's full technological ownership. Similarly, Asian countries may prioritize filing with the Chinese National Intellectual Property Administration. Data at the EPO are presented later to better contextualize the performance of Canada and other countries.

Table X Technological performance of the world's leading countries at the USPTO (2012–2023)

| Country | Technological output | | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | Flow of IP | GR | GI | ARC | Score | Rank |
| **World** | **3,743,285** | **3,743,285** | | **0%** | **1.13** | **1.00** | **1.00** | - | - |
| United States | 1,861,816 | 1,873,669 | | 7% | 1.13 | 1.00 | 1.33 | 0.458 | 1 |
| Japan | 603,239 | 606,913 | | 1% | 0.92 | 0.81 | 0.54 | 0.166 | 5 |
| South Korea | 237,718 | 238,936 | | 3% | 1.28 | 1.13 | 0.65 | 0.135 | 8 |
| Germany | 178,051 | 181,440 | | -8% | 1.02 | 0.90 | 0.63 | 0.111 | 14 |
| China | 165,211 | 171,848 | | -13% | 2.78 | 2.46 | 0.59 | 0.186 | 3 |
| Taiwan | 136,760 | 141,455 | | -1% | 0.96 | 0.85 | 0.71 | 0.110 | 15 |
| France | 71,328 | 73,645 | | -8% | 0.94 | 0.83 | 0.57 | 0.085 | 19 |
| **Canada** | **58,496** | **59,825** | | **-28%** | **1.05** | **0.93** | **1.00** | **0.130** | **9** |
| United Kingdom | 53,408 | 55,026 | | -34% | 1.26 | 1.11 | 0.90 | 0.129 | 10 |
| Switzerland | 47,400 | 49,287 | | 51% | 1.19 | 1.05 | 1.23 | 0.158 | 6 |
| Netherlands | 42,497 | 43,284 | | 40% | 1.07 | 0.94 | 0.97 | 0.126 | 11 |
| Sweden | 38,450 | 38,899 | | 15% | 1.11 | 0.98 | 0.77 | 0.107 | 16 |
| Israel | 28,634 | 29,056 | | -40% | 1.38 | 1.22 | 1.16 | 0.157 | 7 |
| Italy | 24,106 | 24,704 | | -28% | 1.18 | 1.05 | 0.59 | 0.090 | 18 |
| Singapore | 19,166 | 19,602 | | 63% | 1.26 | 1.12 | 0.78 | 0.113 | 13 |
| Finland | 17,134 | 17,242 | | 5% | 0.93 | 0.83 | 0.64 | 0.083 | 20 |
| Australia | 15,598 | 16,085 | | -24% | 1.14 | 1.01 | 0.79 | 0.107 | 17 |
| Denmark | 12,820 | 13,109 | | -2% | 1.28 | 1.13 | 0.83 | 0.117 | 12 |
| Cayman Islands | 12,528 | 12,973 | | 10514% | 1.17 | 1.03 | 0.91 | 0.253 | 2 |
| Ireland | 12,426 | 12,701 | | 53% | 1.76 | 1.56 | 1.16 | 0.173 | 4 |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, flow of technological property (Flow of IP), growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among selected countries. Impact indicators are not calculated for entities with fewer than 30 full patents with a relative impact score. These are displayed as N/C. Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).

Source: Computed by Science-Metrix using USPTO data from PatentsView.

The total number of patents granted by the USPTO peaked in 2019 and there has been a slow decline since then. This may in part be due to USPTO decisions in 2019 to improve patent quality combined

with persisting issues related to patent pendency.[16] As the biggest filer of patents, the United States, not surprisingly, perfectly mirrored the global trend (US GI = 1.0). Japan has shown a steady decline in granted patents over the period, aside from the outlier years of 2020 and 2021 (GR = 0.92; GI = 0.81). China has exhibited an incredible amount of growth over the period with a growth ratio significantly exceeding that of all other countries (GR = 2.78). China had roughly 4,000 patents granted in 2012 and nearly 23,000 in 2023. Ireland (GR = 1.76; GI = 1.56) had the second highest growth, followed by Israel (GR = 1.38; GI = 1.22). Canada had a modest growth rate that was below the world level (GR = 1.05; GI = 0.93), ranking 15th. Along with Canada and Japan, 6 other countries have had a GI below 1.0 (Sweden GI = 0.98; Netherlands GI = 0.94; Germany GI = 0.90; Taiwan GI = 0.85; France GI = 0.83; Finland GI = 0.83).

Flow of IP provides insight into the balance between where inventors are from and where patents are owned, at the time the patent was granted. Negative flow of IP indicates that a country owns the IP rights on fewer patented inventions than it created whereas positive flow of IP indicates that a country owns the IP rights on more patented inventions than it created. Among the top 20 countries analysed, the Cayman Islands stands out for its exceptionally high flow of IP (Flow of IP = 10,514%). This is likely because of taxation conditions in the Cayman Islands that result in a high number of companies being incorporated there. Setting aside the Cayman Islands, flow of IP ranges from a high of 63% in Singapore to a low of -40% in Israel. Following Singapore, the leaders in flow of IP were Ireland (53%), Switzerland (51%) and Netherlands (40%). Canada had a negative flow of IP (-28%), indicating a sizable deficit in ownership of the technological innovations contributed by Canadian at the benefit of foreign economies. Canada was on par with Australia (-24%), Italy (-28%) and the United Kingdom (-34%), presenting the third most negative balance among the top 20 countries. As seen in the previous report, the United States and Japan had a fairly flat flow of IP, along with South Korea, Taiwan, Finland and Denmark.

In terms of the inventions' impact, most of the top countries score below the world median. The countries that score above are limited to (in descending order of rank) the United States (ARC = 1.33), Switzerland (ARC = 1.23), Israel (ARC = 1.16) and Ireland (ARC = 1.16). Canada's impact was on par with the world level. Among those with an ARC below world level, only four had a score above 0.80: the Netherlands (ARC = 0.97), the Cayman Islands (ARC = 0.91), the United Kingdom (ARC = 0.90), and Denmark (ARC = 0.83). Japan (ARC = 0.54), China (ARC = 0.57) and France (ARC = 0.57) had the lowest ARC scores. This high count of countries below the world level is caused by the high representation of the US in the database, its ARC of 1.33 for its large pool of patents balancing the scores of most countries scoring below the world level.

The composite indicator for patents and for all fields of technology allocates a 30% weight to technological output (in fractional counting), a 30% weight to the GR, a 20% weight to the ARC and a 20% weight to the flow of IP. According to this measure, the US ranks 1st (Table X), followed by Cayman Islands, China, Ireland, and Japan in 5th place. Canada ranks in 9th place, likely due to the low flow of IP. Highly patenting countries such as Germany, Taiwan and France rank lower based on composite indicator due to their low impact.

[16] https://www.uspto.gov/blog/working-together-tackle-patent-and-trademark-pendency

### 3.1.2 Technological output and impact at the EPO

Of the 1.1 million patents granted by the EPO between 2011 and 2022, roughly a quarter of them (23.8% of total based on fractional counting) are owned by US patentees (Table XI), a much lower share than that reported at the USPTO, which is to be expected as European nations are now the ones with market advantage and account for a larger share of the patents. Germany patentees own just under 200,000 patents (17.5% of total). With just over 18,000 patents (16.2% of total), Japan now ranks 3rd. France, South Korea, Switzerland and China are 4th, 5th, 6th, and 7th, respectively, with 40,000–75,000 patents each (3.7–6.8% of total). Canada ranks in 13th place with a total of 13,000 patents (1.1%), behind a set of European countries, including Italy, the United Kingdom, the Netherlands, Sweden and Austria. While Canada's share of total output at EPO is slightly lower than that measured at the USPTO (1.1% against 1.6%), it is not that far off, and Canada's decrease in ranking at the EPO mostly comes from other nations taking a much larger share of the total output, mostly at the expense of the United States. In comparison, Japan's share remains mostly unchanged across both offices, at around 16%. The ranking with respect to full counting is identical to the ranking based on fractional counting since the vast majority of patents are filed by a single assignee.

The total number of patents granted by the EPO peaked in 2019 after tremendous growth (World GR = 1.64) and there has been a slow decline since then. This may be in part due to a push to process a large backlog of untreated patent applications.[17] The United States, the biggest filer of patents, helped drive that growth with a GR of 1.83. Other notable contributors to that growth include South Korea (GR = 2.89), China (GR = 4.56) and Taiwan (GR = 2.00). Germany, while still growing its patent output, has seen a steady decline in its share of granted patents over the period, its output not growing as fast as most other countries (GI = 0.78, 20th). China has exhibited an incredible amount of growth over the period with a growth ratio significantly exceeding that of all other countries (GR = 5.56). China had roughly 500 patents granted in 2011 and nearly 6,000 in 2022, emerging from 16th position to 4th. South Korea also moved up position in the ranking, starting in 10th position in 2011 and reaching 6th position by 2022. Canada had a modest growth rate that was below the world level (GR = 1.51; GI = 0.92), ranking 14th, a position similar to its 15th position in GR at the USPTO. Overall, 11 countries had a GI below 1.0.

[17] https://www.nlo.eu/en/news/top-5-highlights-epo-annual-review-2021

Table XI Technological performance of the world's leading countries at the EPO (2011–2022)

| Country | Technological output | | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | Flow of IP | GR | GI | ARC | Score | Rank |
| **World** | **1,118,785** | **1,118,785** | | **0%** | **1.64** | **1.00** | **1.00** | - | - |
| United States | 266,249 | 269,693 | | 1% | 1.83 | 1.11 | 1.18 | 0.405 | 1 |
| Germany | 196,167 | 200,202 | | -2% | 1.28 | 0.78 | 1.18 | 0.319 | 2 |
| Japan | 181,737 | 183,256 | | 1% | 1.46 | 0.89 | 0.60 | 0.264 | 3 |
| France | 76,460 | 78,630 | | -2% | 1.44 | 0.88 | 0.78 | 0.157 | 4 |
| South Korea | 47,454 | 47,875 | | 2% | 2.89 | 1.76 | 0.80 | 0.144 | 7 |
| Switzerland | 43,121 | 45,378 | | 61% | 1.40 | 0.85 | 1.17 | 0.147 | 6 |
| China | 41,654 | 42,210 | | -7% | 4.56 | 2.77 | 0.73 | 0.154 | 5 |
| Italy | 34,935 | 35,420 | | -14% | 1.34 | 0.82 | 1.07 | 0.130 | 9 |
| United Kingdom | 33,811 | 35,696 | | -23% | 1.59 | 0.97 | 1.07 | 0.132 | 8 |
| Netherlands | 32,181 | 34,778 | | 16% | 1.70 | 1.03 | 0.98 | 0.125 | 12 |
| Sweden | 30,125 | 30,356 | | 16% | 1.70 | 1.04 | 1.05 | 0.128 | 10 |
| Austria | 14,792 | 15,134 | | -9% | 1.58 | 0.96 | 1.28 | 0.125 | 11 |
| **Canada** | **12,931** | **13,324** | | **-19%** | **1.51** | **0.92** | **1.16** | **0.114** | **15** |
| Finland | 12,442 | 12,513 | | 9% | 1.83 | 1.11 | 1.07 | 0.111 | 16 |
| Belgium | 12,240 | 12,780 | | 1% | 1.54 | 0.94 | 1.11 | 0.110 | 17 |
| Denmark | 10,805 | 11,015 | | 0% | 1.63 | 0.99 | 1.29 | 0.122 | 13 |
| Taiwan | 8,186 | 8,356 | | -1% | 2.00 | 1.22 | 0.76 | 0.086 | 20 |
| Spain | 8,012 | 8,279 | | -23% | 1.69 | 1.03 | 1.03 | 0.101 | 18 |
| Israel | 6,932 | 7,049 | | -20% | 1.83 | 1.11 | 1.31 | 0.121 | 14 |
| Australia | 5,042 | 5,174 | | -20% | 1.48 | 0.90 | 1.04 | 0.096 | 19 |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, flow of technological property (Flow of IP), growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among selected countries. Impact indicators are not calculated for entities with fewer than 30 full patents with a relative impact score. These are displayed as N/C. Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).

Source: Computed by Science-Metrix using EPO data from PATSTAT (Fall 2023).

As described in the previous section, the flow of IP provides insight into the balance between where inventors are from and where patents are owned. Negative flow of IP indicates that a country owns the IP rights on fewer patented inventions than it created whereas positive flow of IP indicates that a country owns the IP rights on more patented inventions than it created. Among the top 20 countries analysed, Switzerland stands out for its high flow of IP (Flow of IP = 61%). Setting aside Switzerland, flow of IP ranges from a high of 16% in Sweden and the Netherlands to a low of -23% in the United Kingdom and Spain. Following Sweden and the Netherlands, the leaders in flow of IP were Finland (9%), South Korea (2%), the United States (1%), Japan (1%) and Belgium (1%). Canada had a negative flow of IP (-19%, 16th), indicating that the technological innovations contributed by Canadian inventors in the European market are owned by foreign institutions more often than not.

Leading countries are Israel (ARC = 1.31), Denmark (ARC = 1.29), Austria (ARC = 1.28), Germany (ARC = 1.18), the United States (ARC = 1.18), Switzerland (ARC = 1.17) and Canada (ARC = 1.16). Canadian patents are among the most cited, a similarity shared across the USPTO and EPO. Among those with an ARC below world level, South Korea (ARC = 0.80), France (ARC = 0.78), Taiwan

(ARC = 0.76), China (ARC = 0.73) and Japan (ARC = 0.60) had the lowest ARC scores. Except for France, the least-cited countries were Asian nations.

The composite indicator for patents and for all fields of technology allocates a 30% weight to technological output (in fractional counting), a 30% weight for to the GR, a 20% weight to the ARC and a 20% weight to the flow of IP. According to this measure, the US ranks 1st (Table XI), followed by Germany, Japan, and France, with China in 5th place. Canada ranks in 15th place, due to its share of patent output, its low flow of IP and lower growth.

## 3.2 Technological performance of Canada's provinces and territories

In this subsection, we explore the performance of Canada's provinces and territories in terms of their ownership of new technology. The attribution of a province or territory to an assignee or an inventor is defined by the city and the address of the assignee or the inventor. Not all addresses could be attributed to a province or territory as some records omit the city, some contain typographical errors and some affiliations are simply unidentifiable, among other issues. Nonetheless, 96% of Canadian addresses at the USPTO were assigned to a province or territory, corresponding to 96% of fractional patents. At the EPO, 99% of all Canadian addresses were assigned to a province or territory.

### 3.2.1 Technological output and impact of Canada's province and territories at the USPTO

Table XII presents technometric indicators for all Canadian provinces and territories. As with the 2016 analysis, Ontario produced just over half (51.1%) of Canada's whole output with 30,000 patents owned, while Quebec contributed to a little over a sixth (17.2%) with 10,000 patents. British Columbia and Alberta follow with 6,700 patents (11.5%) and 5,600 patents (9.6%), respectively. Saskatchewan, Manitoba and Nova Scotia each had approximately 1,000 patents granted, each representing just under 2% of Canada's total output. New Brunswick had 400 patents granted (0.7%), Newfoundland & Labrador had 128 patents granted and Prince Edward Island, Yukon, and Northwest Territories together acquired 55 new patents. As with the 2016 analysis, Nunavut acquired no new patents.

Although Ontario had the highest number of patents, there has been an overall decline in patents by Ontario during the period 2012–2023 (GR = 0.87), which contrasts greatly with the previous study period during which Ontario's GR was 1.86. Ontario's decline in granted patents was the main reason Canada's GI was below the world level over the period 2012–2023. Except for Ontario, Manitoba (GR = 0.97), Prince Edward Island (GR = 0.81), and New Brunswick (GR = 1.00), all other provinces had positive growth ranging from a GR of 1.22 for Alberta to a GR of 2.67 for Nova Scotia. Quebec, with a GR of 1.41, is of note given that in the previous study, it was the only province that saw its output consistently decrease during the previous study period (GR = 0.84 for period 2003–2014).

Table XII Technological performance of Canada's provinces and territories (2012–2023) (USPTO)

| Country | Technological output | | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | Flow of IP | GR | GI | ARC | Score | Rank |
| **Canada** | **58,496** | **59,825** | | **-28%** | **1.05** | **0.93** | **1.00** | - | - |
| Ontario | 29,889 | 30,744 | | -30% | 0.87 | 0.77 | 0.97 | 0.406 | 2 |
| Quebec | 10,051 | 10,395 | | -26% | 1.41 | 1.24 | 0.94 | 0.297 | 4 |
| British Columbia | 6,745 | 7,030 | | -36% | 1.30 | 1.15 | 1.23 | 0.293 | 5 |
| Alberta | 5,588 | 5,764 | | -23% | 1.22 | 1.08 | 0.88 | 0.213 | 7 |
| Saskatchewan | 1,125 | 1,162 | | -11% | 1.51 | 1.33 | 1.12 | 0.305 | 3 |
| Manitoba | 970 | 1,020 | | -8% | 0.97 | 0.86 | 0.77 | 0.141 | 8 |
| Nova Scotia | 925 | 956 | | 46% | 2.67 | 2.36 | 1.44 | 0.709 | 1 |
| New Brunswick | 415 | 427 | | -6% | 1.00 | 0.89 | 0.75 | 0.138 | 9 |
| Newfoundland | 128 | 132 | | -23% | 1.49 | 1.32 | 0.98 | 0.228 | 6 |
| Prince Edward Island | 42 | 46 | | -15% | 0.81 | 0.72 | 0.62 | 0.051 | 10 |
| Yukon | 11 | 11 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Northwest Territories | 2 | 2 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Nunavut | 0 | 0 | | N/C | N/C | N/C | N/C | N/C | N/C |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, flow of technological property (Flow of IP), growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among provinces and territories.
Indicators are not calculated for entities with fewer than 30 full patents. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).
The scale in the trends is not the same across countries.

Source: Computed by Science-Metrix using USPTO data from PatentsView.

In terms of patent ownership deficit, Nova Scotia was the only geographical area within Canada with a positive flow of IP (Table XII). Quebec and Prince Edward Island, which had a positive flow of IP in the previous study (2003–2014) did not retain their positive flow. New Brunswick (-6%), Manitoba (-8%), and Saskatchewan (-11%) were the other top performers in terms of IP retention, but they still presented with a deficit. British Columbia (−36%) and Ontario (-30%) had the largest overall deficits.

Assessing patent impact reveals that only Nova Scotia (ARC = 1.44), British Columbia (ARC = 1.23), and Saskatchewan (ARC = 1.12) had an ARC above the world level. The ARC of Newfoundland (ARC = 0.97), Ontario (ARC = 0.97), Quebec (ARC = 0.94) and Alberta (ARC = 0.88) was just below world level while all other provinces had an ARC below 0.8.

Despite having only 925 patents, Nova Scotia replaced Ontario in first place based on the composite indicator, because of its high GR, Flow of IP, and ARC. Ontario ranked second, followed by Saskatchewan, with Quebec and British Columbia following. That being said, the composite should not take precedence and diminish the importance of Ontario in the Canadian patenting ecosystem, as the province by itself accounts for more than half of new patents. Still, the fact that Nova Scotia was able to overtake Ontario for 1st place on the composite is a testament to its emergence in the Canadian innovation landscape, but also a warning about Ontario's stagnating patenting activity. Ontario's loss of BlackBerry, its main engine in terms of patenting activity, is a situation not that different from the one Quebec faced in the previous decade with the dissolution of Nortel, as reflected in the province's performance in the 2016 report.

### 3.2.2 Technological output and impact of Canada's province and territories at the EPO

Table XIII presents technometric indicators for all Canadian provinces and territories. Ontario produced 62% of Canada's whole output with 8,000 patents owned, while Quebec contributed to a little over a sixth (18.6%), with 2,400 patents. British Columbia and Alberta follow with 1,200 patents (9.0%) and 700 patents (5.2%), respectively. Manitoba, Nova Scotia and Saskatchewan each had approximately 100–160 patents granted, each representing about 1% of Canada's total output. Prince Edward Island had 80 patents granted (0.6%), New Brunswick had 63 patents granted (0.5%) and Newfoundland & Labrador had 20 patents granted (0.2%). Overall, Ontario and Quebec accounted together for close to 81% of all Canadian patents at the EPO, higher than their 68% share at the USPTO. Most of the increase came from Ontario, which increased its share by 11 points, while Quebec saw a minimal increase of 1.4 points.

Although Ontario had the highest number of patents, the decline observed at the USPTO was also somewhat detected at the EPO, with Ontario presenting with one of the smallest growth rates during the period 2011–2022 (GR = 1.32), third to last just ahead of Newfoundland and Labrador (GR = 0.81) and Prince Edward Island (GR = 0.72). Ontario not keeping up with global growth trends in granted patents was again the main reason Canada's GI was below the world level over the period 2012–2023, as most of the top patenting provinces presented with a GI above 1.00. Indeed, except for Ontario, Manitoba (GI = 0.96), New Brunswick (GI = 0.87), Newfoundland and Labrador (GI = 0.72) and Prince Edward Island (GI = 0.44), all other provinces had stronger growth than the world average, from a GI of 1.05 for Quebec to a GI of 1.54 for Nova Scotia.

Table XIII Technological performance of Canada's provinces and territories (2011–2022) (EPO)

| Country | Technological output | | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | Flow of IP | GR | GI | ARC | Score | Rank |
| **Canada** | **12,931** | **13,324** | | **-19%** | **1.51** | **0.92** | **1.16** | - | - |
| Ontario | 8,016 | 8,183 | | -10% | 1.32 | 0.80 | 1.08 | 0.455 | 1 |
| Quebec | 2,400 | 2,575 | | -32% | 1.72 | 1.05 | 1.06 | 0.278 | 6 |
| British Columbia | 1,161 | 1,224 | | -33% | 2.20 | 1.34 | 1.28 | 0.314 | 5 |
| Alberta | 668 | 696 | | -26% | 2.45 | 1.49 | 1.01 | 0.342 | 4 |
| Manitoba | 161 | 169 | | -21% | 1.57 | 0.96 | 1.61 | 0.197 | 8 |
| Nova Scotia | 127 | 134 | | -9% | 2.52 | 1.54 | 0.48 | 0.350 | 3 |
| Saskatchewan | 105 | 117 | | -35% | 2.03 | 1.24 | 10.34 | 0.422 | 2 |
| Prince Edward Island | 79 | 80 | | 97% | 0.72 | 0.44 | 0.17 | 0.203 | 7 |
| New Brunswick | 63 | 65 | | -4% | 1.42 | 0.87 | 0.58 | 0.175 | 9 |
| Newfoundland and Labrador | 20 | 20 | | -15% | 0.81 | 0.72 | 0.62 | 0.051 | 10 |
| Yukon | 3 | 3 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Northwest Territories | 0 | 0 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Nunavut | 0 | 0 | | N/C | N/C | N/C | N/C | N/C | N/C |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, flow of technological property (Flow of IP), growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among provinces and territories.
Indicators are not calculated for entities with fewer than 30 full patents. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).
The scale in the trends is not the same across countries.

Source: Computed by Science-Metrix using USPTO data from PatentsView.

In terms of patent ownership deficit, Prince Edward Island was the only geographical area within Canada with a positive flow of IP (Table XIII). Notably, Ontario, which presented with the largest deficit at the USPTO, performed much better at EPO, with a flow of -10%, the 4th highest among provinces, only behind Nova Scotia (-9%) New Brunswick (-4%) and Prince Edward Island (+97%). Saskatchewan (-35%), British Columbia (-33%) and Quebec (-32%) had the largest overall deficits.

Assessing patent impact reveals Saskatchewan stands out with a very high score (ARC = 10.34). Because its score is based on only 100 patents, it is possible that this high score is the reflection of a few extremely cited outliers; thus, caution is advised as it is not expected that Saskatchewan will maintain such high impact as its number of patents keeps increasing in the coming years. Manitoba (ARC = 1.61), British Columbia (ARC = 1.28), Ontario (ARC = 1.08), Quebec (ARC = 1.06) and Alberta (ARC = 1.01) had an ARC above the world level. All the other provinces had an ARC below 0.65.

Ontario was ranked 1st among provinces at the EPO based on the composite indicator, because of its high level of output, its less negative Flow of IP, and ARC. Saskatchewan ranked second, boosted by its strong growth, but mostly its ARC, and is followed by Nova Scotia with Alberta and British Columbia following. Quebec, the second largest contributor to Canadian patents, only ranked 6th on the composite, dragged down by its low Flow of IP, and strong growth and ARC that were both still weaker than many other provinces. That being said, at close to 20%, Quebec's contribution to the Canada's patenting activity in the European market should not disregarded, and the gap on the composite between the 3rd and 6th positions is of 0.072 (0.350 against 0.278), and different weights could have led to notable changes in the ranking around these positions.

### 3.2.3 Technological output and impact of Canada's cities at the USPTO

Table XIV presents technometric indicators for the Canada's top 50 cities based on fractional patent count. Given Ontario's high output of patents, it is unsurprising that the majority of cities on the list are in Ontario. Waterloo tops the list with 8,600 patents (by fractional counting). Although patent output from Waterloo, headquarters of BlackBerry, has declined over the period (GR = 0.37) and the impact of these patents has been below average (ARC = 0.93), a high flow of IP (85%) along with a high patent output result in Waterloo taking the top rank based on composite indicator score. Toronto had the second highest output, with approximately 6,000 patents. Toronto had a negative flow of IP (-38%) but ranks 3rd based on composite indicator score because of its high growth during the period (GR = 1.63; GI = 1.45) and above average impact (ARC = 1.10). Ottawa, Montréal, Calgary, and Vancouver had similar patent metrics with 2,800–3,500 patents, a negative flow of IP, moderately high growth (GR of 1.24–1.48, except for Ottawa, which had GR of 0.79) and ranked 8th–11th based on composite indicator score. The next group of cities, consisting of Longueuil, Mississauga, Edmonton, Burnaby, Quebec City, and Markham each had 1,000–2,000 patents. Among this group of cities, Burnaby stands apart for having the highest impact (ARC = 1.81) and Longueuil stands apart for having a high flow of IP (323%) and high growth (GR = 2.52). Aside from Burnaby, the cities that had the highest average impact also had higher growth rates. Halifax, Oakville, Newmarket, Valcourt, Kirkland, and Kitchener all had ARC ranging from 1.42–1.60 and GR from 1.44–3.38. While Burnaby had the highest ARC, its GR was modest at 1.10.

The majority of cities on the list of top 50 had a negative flow of IP, ranging from -17% to -81%. Among the small minority of cities that had a positive flow of IP, the highest flow of IP was observed for cities in Quebec (Valcourt flow of IP = 691%; Dorval flow of IP = 360%; Longueuil flow of IP = 323%). These cities host established corporations, including Bombardier Recreational Products in Valcourt and Pratt & Whitney in Longueuil. Two east coast cities also had a high flow of IP (Moncton flow of IP = 101%; Halifax flow of IP = 59%).

## Table XIV Technological performance of Canada's cities (2012–2023) (USPTO)

| Country | Technological output | | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | Flow of IP | GR | GI | ARC | Score | Rank |
| **Canada** | **58,496** | **59,825** | | **-28%** | **1.05** | **0.93** | **1.00** | - | - |
| Waterloo (ON) | 8,597 | 8,720 | | 85% | 0.37 | 0.33 | 0.93 | 0.378 | 1 |
| Toronto | 5,960 | 6,310 | | -38% | 1.63 | 1.45 | 1.10 | 0.301 | 3 |
| Ottawa | 3,526 | 3,680 | | -68% | 0.79 | 0.70 | 0.95 | 0.176 | 11 |
| Montréal | 3,473 | 3,710 | | -36% | 1.24 | 1.10 | 0.81 | 0.190 | 10 |
| Calgary | 3,285 | 3,386 | | -25% | 1.29 | 1.14 | 0.93 | 0.192 | 9 |
| Vancouver | 2,864 | 3,057 | | -38% | 1.48 | 1.31 | 1.21 | 0.193 | 8 |
| Longueuil | 1,731 | 1,754 | | 323% | 2.52 | 2.23 | 1.03 | 0.270 | 5 |
| Mississauga | 1,562 | 1,674 | | -36% | 0.79 | 0.70 | 0.80 | 0.109 | 19 |
| Edmonton | 1,175 | 1,247 | | -40% | 1.03 | 0.91 | 0.88 | 0.105 | 21 |
| Burnaby | 1,170 | 1,231 | | 7% | 1.10 | 0.97 | 1.81 | 0.160 | 13 |
| Quebec City | 1,096 | 1,183 | | -23% | 1.20 | 1.07 | 0.92 | 0.114 | 18 |
| Markham | 1,019 | 1,196 | | -28% | 0.91 | 0.81 | 0.68 | 0.091 | 26 |
| Vaughan | 793 | 834 | | 2% | 1.27 | 1.12 | 1.19 | 0.123 | 17 |
| Saskatoon | 747 | 777 | | -17% | 1.89 | 1.67 | 1.27 | 0.139 | 15 |
| Winnipeg | 721 | 762 | | -19% | 0.98 | 0.86 | 0.77 | 0.088 | 29 |
| Halifax | 714 | 737 | | 59% | 3.38 | 2.99 | 1.56 | 0.215 | 7 |
| Kitchener | 601 | 656 | | -69% | 3.43 | 3.03 | 1.42 | 0.174 | 12 |
| London | 559 | 603 | | -48% | 0.96 | 0.85 | 0.75 | 0.074 | 41 |
| Oakville | 542 | 585 | | -65% | 2.31 | 2.04 | 1.50 | 0.142 | 14 |
| Richmond (BC) | 518 | 556 | | -26% | 0.98 | 0.87 | 0.97 | 0.088 | 28 |
| Aurora | 384 | 399 | | 50% | 0.93 | 0.82 | 1.00 | 0.103 | 22 |
| Hampton | 376 | 376 | | -22% | 7.34 | 6.50 | 1.02 | 0.280 | 4 |
| Hamilton | 369 | 419 | | -60% | 1.29 | 1.14 | 1.00 | 0.085 | 31 |
| Valcourt | 326 | 328 | | 691% | 1.60 | 1.41 | 1.47 | 0.306 | 2 |
| Victoria | 303 | 330 | | -49% | 1.45 | 1.29 | 0.82 | 0.083 | 33 |
| Dorval | 298 | 305 | | 360% | 2.73 | 2.42 | 0.84 | 0.228 | 6 |
| Burlington | 271 | 299 | | -54% | 1.08 | 0.95 | 0.88 | 0.071 | 44 |
| Newmarket | 263 | 279 | | -22% | 1.78 | 1.57 | 1.49 | 0.127 | 16 |
| Kingston | 257 | 291 | | -39% | 1.15 | 1.02 | 1.29 | 0.095 | 23 |
| Surrey | 245 | 275 | | -64% | 1.35 | 1.19 | 0.89 | 0.077 | 40 |
| Laval | 243 | 285 | | -68% | 1.22 | 1.08 | 0.92 | 0.073 | 43 |
| Richmond Hill | 243 | 284 | | -77% | 1.00 | 0.88 | 1.14 | 0.074 | 42 |
| Caledon | 206 | 216 | | 32% | 0.70 | 0.62 | 0.81 | 0.077 | 39 |
| Cambridge (ON) | 206 | 226 | | -48% | 0.78 | 0.69 | 0.77 | 0.057 | 47 |
| Sherbrooke | 195 | 219 | | -58% | 1.29 | 1.14 | 1.09 | 0.083 | 32 |
| Brampton | 192 | 229 | | -69% | 1.01 | 0.89 | 1.32 | 0.082 | 34 |
| Kirkland | 185 | 207 | | -50% | 1.44 | 1.27 | 1.46 | 0.106 | 20 |
| North Vancouver | 183 | 206 | | -72% | 1.38 | 1.23 | 1.20 | 0.087 | 30 |
| Windsor | 177 | 199 | | -75% | 1.06 | 0.94 | 0.63 | 0.052 | 48 |
| Kelowna | 167 | 185 | | -52% | 1.42 | 1.26 | 0.84 | 0.077 | 38 |
| Guelph | 166 | 190 | | -73% | 1.72 | 1.52 | 0.78 | 0.078 | 35 |
| Moncton | 158 | 163 | | 101% | 0.87 | 0.77 | 0.64 | 0.091 | 27 |
| Drummondville | 145 | 152 | | 8% | 1.50 | 1.33 | 0.77 | 0.091 | 24 |
| Thornill | 134 | 176 | | -81% | 0.69 | 0.61 | 0.68 | 0.039 | 50 |
| Langley | 126 | 137 | | -50% | 1.45 | 1.29 | 0.84 | 0.077 | 36 |
| Brossard | 126 | 151 | | -72% | 2.00 | 1.77 | 0.90 | 0.091 | 25 |
| Pointe-Claire | 125 | 142 | | -28% | 0.75 | 0.66 | 0.58 | 0.050 | 49 |
| Regina | 122 | 127 | | -17% | 0.85 | 0.75 | 0.81 | 0.066 | 45 |
| Barrie | 118 | 129 | | -56% | 1.11 | 0.98 | 1.12 | 0.077 | 37 |
| Boucherville | 111 | 127 | | -44% | 1.10 | 0.98 | 0.68 | 0.061 | 46 |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, flow of technological property (Flow of IP), growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among cities.
Impact indicators are not calculated for entities with fewer than 30 full patents with a relative impact score. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).

Source: Computed by Science-Metrix using USPTO data from PatentsView.

### 3.2.4 Technological output and impact of Canada's cities at the EPO

Table XV presents technometric indicators for Canada's top 50 cities based on fractional patent count. Given Ontario's higher contribution at the EPO, its cities occupy most of the list. Readers will note a small difference in the way cities are reported at the EPO, with some cities merged compared to what is presented at the USPTO. This is because the EPO, contrary to the USPTO, does provide enriched data fields with geographical coding of sub-divisions in Canada, which include census divisions. This will have some impact on mostly smaller metropolitan areas, where some of the core cities are merged at the EPO.

Waterloo tops the list with 4,300 patents (by fractional counting). Patent output from Waterloo, headquarters of BlackBerry, has increased over the period (GR = 1.20), but not at the same level observed for Canada (GR = 1.51) and much slower than at the world level (GI = 0.73), and the impact of its patents has been slightly above average (ARC = 1.05). Combined with one of the strongest flows of IP (78%) along with a high patent output, Waterloo takes the top rank based on composite indicator score, as it did at the USPTO. Toronto ranks second with close to 1,600 patents, followed by Montréal (1,100 patents). Vancouver currently ranks 4th in output. Ottawa, Peel, Calgary, Longueuil, Quebec City, Edmonton, Middlesex, Winnipeg, Halifax, Halton and Sherbrooke follow with a range of 100–700 patents.

# Table XV Technological performance of Canada's cities (2011–2022) (EPO)

| Country | Technological output | | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | Flow of IP | GR | GI | ARC | Score | Rank |
| **Canada** | **12,931** | **13,324** | | **-19%** | **1.51** | **0.92** | **1.16** | - | - |
| Waterloo (ON) | 4,319 | 4,352 | | 78% | 1.20 | 0.73 | 1.05 | 0.474 | 1 |
| Toronto | 1,597 | 1,689 | | -10% | 1.74 | 1.06 | 1.48 | 0.260 | 4 |
| Montréal | 1,068 | 1,199 | | -30% | 1.52 | 0.92 | 1.02 | 0.189 | 12 |
| Vancouver | 1,047 | 1,107 | | -29% | 2.26 | 1.38 | 1.31 | 0.235 | 7 |
| Ottawa | 704 | 726 | | -70% | 0.95 | 0.58 | 0.71 | 0.098 | 25 |
| Peel | 625 | 649 | | -16% | 1.18 | 0.72 | 0.65 | 0.144 | 20 |
| Calgary | 473 | 492 | | -10% | 2.65 | 1.62 | 1.09 | 0.227 | 8 |
| Longueuil | 438 | 454 | | -1% | 2.83 | 1.73 | 0.99 | 0.240 | 5 |
| Quebec City | 315 | 333 | | -30% | 1.83 | 1.11 | 1.54 | 0.162 | 16 |
| Edmonton | 165 | 175 | | -50% | 2.05 | 1.25 | 0.90 | 0.141 | 21 |
| Middlesex | 163 | 171 | | -22% | 1.95 | 1.19 | 0.36 | 0.146 | 19 |
| Winnipeg | 145 | 152 | | -13% | 1.60 | 0.97 | 1.61 | 0.151 | 17 |
| Halifax | 116 | 121 | | -5% | 2.86 | 1.74 | 0.34 | 0.206 | 10 |
| Halton | 112 | 115 | | -73% | 2.25 | 1.37 | 2.03 | 0.149 | 18 |
| Sherbrooke | 97 | 100 | | -19% | 1.34 | 0.82 | 0.96 | 0.119 | 24 |
| Saskatoon | 84 | 93 | | -35% | 1.83 | 1.11 | 12.83 | 0.321 | 3 |
| Laval | 82 | 86 | | -62% | 1.09 | 0.67 | 0.17 | 0.060 | 28 |
| Verchères | 73 | 78 | | -5% | 1.27 | 0.77 | 1.78 | 0.135 | 22 |
| Kings (PE) | 70 | 70 | | 207% | 0.60 | 0.36 | 0.19 | 0.224 | 9 |
| Hamilton | 68 | 78 | | -55% | 2.63 | 1.60 | 2.02 | 0.180 | 14 |
| Niagara Falls | 63 | 63 | | -13% | 1.51 | 0.92 | 1.21 | 0.134 | 23 |
| Durham | 59 | 60 | | -48% | 3.90 | 2.38 | 0.75 | 0.236 | 6 |
| Capital, BC | 49 | 50 | | -51% | 1.45 | 0.88 | 0.69 | 0.094 | 26 |
| Wellington, ON | 42 | 49 | | -55% | 2.55 | 1.55 | 2.04 | 0.174 | 15 |
| Frontenac, ON | 39 | 40 | | -60% | 0.99 | 0.60 | 0.78 | 0.062 | 27 |
| Essex, ON | 36 | 42 | | -67% | 3.56 | 2.17 | 0.33 | 0.196 | 11 |
| Renfrew, ON | 33 | 33 | | -20% | 5.60 | 3.41 | 0.73 | 0.350 | 2 |
| Drummond, QC | 32 | 32 | | 6% | 1.17 | 0.71 | N/C | N/C | N/C |
| Thérèse-De Blainville | 31 | 31 | | -38% | 2.88 | 1.75 | 1.07 | 0.188 | 13 |
| Lambton, ON | 31 | 31 | | -20% | 0.27 | 0.16 | 0.14 | 0.040 | 29 |
| La Vallée-du-Richelieu, QC | 23 | 27 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Mirabel | 21 | 33 | | 127% | N/C | N/C | 24% | N/C | N/C |
| Le Saguenay-et-son-Fjord, QC | 20 | 20 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Lévis | 19 | 19 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Saint John (NB) | 19 | 19 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Division 2, NL | 19 | 19 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Simcoe, ON | 17 | 18 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Granby | 17 | 17 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Fraser Valley, BC | 17 | 17 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Chatham-Kent, ON | 17 | 17 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Kelowna | 16 | 17 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Brant, ON | 15 | 15 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Westmorland, NB | 15 | 15 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Fredericton | 15 | 16 | | N/C | N/C | N/C | N/C | N/C | N/C |
| L'Amiante, QC | 14 | 15 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Peterborough, ON | 14 | 14 | | N/C | N/C | N/C | N/C | N/C | N/C |
| L'Assomption | 13 | 15 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Memphrémagog, QC | 11 | 11 | | N/C | N/C | N/C | N/C | N/C | N/C |
| La Rivière-du-Nord, QC | 11 | 11 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Regina | 10 | 12 | | N/C | N/C | N/C | N/C | N/C | N/C |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, flow of technological property (Flow of IP), growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among cities.
Impact indicators are not calculated for entities with fewer than 30 full patents with a relative impact score. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).

Source: Computed by Science-Metrix using USPTO data from PatentsView.

### 3.2.5 Technological output and impact of a selection of Canadian CMAs at the USPTO

Table XVI presents technometric indicators at the USPTO for a selection of Canada's largest CMAs. While Waterloo ranked 1st when considering official city definitions, it is in fact the Toronto's census metropolitan area which comes 1st, with slightly more than 11,600 patents, with most of its output coming from the cities of Toronto, Mississauga, Markham and Vaughan. The CMA of Kitchener–Cambridge–Waterloo ranks 2nd with close to 9,500 patents, 90% of these coming from Waterloo itself. Montréal ranks 3rd with almost 7,000 patents, half of it coming from the core city itself (3,500 patents), but with an important contribution from Longueuil (1,700 patents), and Dorval and Laval on a smaller scale (245 patents and 298 patents, respectively). Vancouver places 4th with 5,500 patents, with Ottawa–Gatineau closing the top 5 with 3,600 patents.

Major metropolitan areas are typically driving innovation, and growth in patenting activity among the selected CMAs reflects this, with all 8 of the 12 CMAs with a computed GR presenting with stronger growth than the Canadian average. Among these, 7 present with stronger growth than the world level, the exception being Edmonton (GR = 1.08, GI = 0.96). The strongest growth is observed in the Halifax CMA (GR = 3.37), followed by Saskatoon (GR = 1.89) and Montréal (GR = 1.53). While the growth in the first two CMAs is impressive, the starting levels of output for these was quite low (around 100 patents in the first 6 years), therefore indicating the emergence of a more robust innovation ecosystem with patenting activity. The case of Montréal is different as the CMA is among the top patenting areas in Canada, and the observed growth has helped the region solidify its 3rd position. Indeed, for the 2012–2017 period, Montréal, while ranking 3rd with 2,700 patents, was only slightly above Vancouver (2,300 patents) and Ottawa–Gatineau (2,000 patents). For the last 6-year period of 2018–2023, Montréal ranked 2nd with 4,200 patents, slightly closing the gap with Toronto in terms of relative differences, overtaking Kitchener–Cambridge–Waterloo (2,900 patents) and opening much larger leads against Vancouver (3,100 patents) and Ottawa–Gatineau (1,900 patents). While the city of Montréal itself saw its output increase, a large share of the growth came from Longueuil, which appears to have become an important contributor of patents for the region.

Among selected CMAs, only three presented with a positive flow of IP: Halifax (+69%), Kitchener–Cambridge–Waterloo (+47%) and Moncton (+35%). Ottawa–Gatineau suffers the highest deficit in ownership with a negative flow of -65%.

The most impactful patents were granted for organizations headquartered in the CMAs of Halifax (ARC = 1.59), Vancouver (ARC = 1.29) and Saskatoon (ARC = 1.26). Toronto was the only other selected CMA with an ARC above the world level (ARC = 1.03), with most remaining CMAs presenting on par or slightly below world average impact.

Combining multiple dimensions in a composite indicator results in the CMA of Halifax ranking 1st among selected CMAs, boosted by its strong growth, flow of IP and impact, the highest in all cases. Toronto's CMA ranked 2nd because of its high level of output and strong growth, followed by Kitchener–Cambridge–Waterloo, Vancouver and Montréal.

Table XVI Technological performance of a selection of Canadian CMAs (2012–2023) (USPTO)

| Country | Technological output | | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | Flow of IP | GR | GI | ARC | Score | Rank |
| **Canada** | **58,496** | **59,825** | | **-28%** | **1.05** | **0.93** | **1.00** | - | - |
| Toronto | 11,645 | 12,225 | | -35% | 1.30 | 1.15 | 1.03 | 0.521 | 2 |
| Kitchener-Cambridge-Waterloo | 9,462 | 9,613 | | 47% | 0.45 | 0.40 | 0.95 | 0.481 | 3 |
| Montréal | 6,928 | 7,193 | | -24% | 1.53 | 1.36 | 0.93 | 0.415 | 5 |
| Vancouver | 5,491 | 5,761 | | -35% | 1.30 | 1.15 | 1.29 | 0.420 | 4 |
| Ottawa-Gatineau | 3,626 | 3,783 | | -65% | 0.80 | 0.71 | 0.94 | 0.198 | 10 |
| Calgary | 3,360 | 3,464 | | -18% | 1.30 | 1.15 | 0.92 | 0.307 | 7 |
| Edmonton | 1,358 | 1,437 | | -37% | 1.08 | 0.96 | 0.85 | 0.190 | 11 |
| Québec | 1,184 | 1,269 | | -19% | 1.23 | 1.09 | 0.94 | 0.245 | 8 |
| Halifax | 811 | 834 | | 69% | 3.37 | 2.98 | 1.53 | 0.721 | 1 |
| Saskatoon | 753 | 783 | | -11% | 1.89 | 1.67 | 1.26 | 0.388 | 6 |
| Winnipeg | 721 | 762 | | -9% | 0.98 | 0.86 | 0.77 | 0.185 | 12 |
| Moncton | 172 | 177 | | 35% | 0.92 | 0.82 | 0.64 | 0.201 | 9 |
| Charlottetown | 25 | 29 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Whitehorse | 10 | 10 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Yellowknife | 2 | 2 | | N/C | N/C | N/C | N/C | N/C | N/C |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, flow of technological property (Flow of IP), growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among cities.
Impact indicators are not calculated for entities with fewer than 30 full patents with a relative impact score. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).
Source: Computed by Science-Metrix using USPTO data from PatentsView.

### 3.2.6 Technological output and impact of a selection of Canadian CMAs at the EPO

Table XVII presents technometric indicators at the EPO for the same selection of CMAs. While Toronto's CMA ranked 1st at the USPTO, it is in fact the Kitchener–Cambridge–Waterloo which comes 1st at the EPO, with slightly more than 4,300 patents, well ahead of Toronto's CMA which stood 2nd with 2,400 patents. Montréal's CMA ranked 3rd with 1,800 patents, followed by Vancouver (1,000 patents) and Ottawa–Gatineau (713 patents).

While growth was observed in all the selected CMAs except for Ottawa–Gatineau (GR = 0.95), only Saskatoon (GR = 2.86, GI = 1.74), Calgary (GR = 2.65, GI = 1.62), Vancouver (GR = 2.26, GI = 1.38) and Edmonton (GR = 2.05, GI = 1.25) presented with substantially stronger growth than the world average. However, with the exception of Vancouver, these CMAs had limited patent output at the EPO.

Among selected CMAs, only one presented with a positive flow of IP: Kitchener–Cambridge–Waterloo (+82%). Halifax ranked 2dn with a net balance of -2%. Ottawa–Gatineau suffered the highest deficit in ownership with a negative flow of -82%, ranking last at both the EPO and USPTO.

The most impactful patents were granted for organizations headquartered in the CMAs of Saskatoon (ARC =12.83), Winnipeg (ARC = 1.61), Québec (ARC = 1.56), Vancouver (ARC = 1.31) and Toronto (ARC = 1.27).

Combining multiple dimensions in a composite indicator results in the CMA of Kitchener–Cambridge–Waterloo ranking 1st among selected CMAs, boosted by its flow of IP and growth. Halifax's CMA ranked 2nd because of its growth, impact and relatively high flow of IP, followed by Calgary, Saskatoon and Toronto.

Table XVII Technological performance of a selection of Canadian CMAs (2011–2022) (EPO)

| Country | Technological output | | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | Flow of IP | GR | GI | ARC | Score | Rank |
| **Canada** | **12,931** | **13,324** | | **-19%** | **1.51** | **0.92** | **1.16** | - | - |
| Kitchener-Cambridge-Waterloo | 4,319 | 4,352 | | 82% | 1.20 | 0.73 | 1.05 | 0.551 | 1 |
| Toronto | 2,393 | 2,503 | | -19% | 1.62 | 0.98 | 1.27 | 0.352 | 5 |
| Montréal | 1,779 | 1,934 | | -29% | 1.75 | 1.06 | 0.98 | 0.313 | 7 |
| Vancouver | 1,047 | 1,107 | | -27% | 2.26 | 1.38 | 1.31 | 0.350 | 6 |
| Ottawa-Gatineau | 713 | 735 | | -70% | 0.95 | 0.58 | 0.71 | 0.055 | 11 |
| Calgary | 473 | 492 | | -7% | 2.65 | 1.62 | 1.09 | 0.394 | 3 |
| Québec | 334 | 352 | | -32% | 1.80 | 1.10 | 1.56 | 0.226 | 8 |
| Edmonton | 165 | 175 | | -48% | 2.05 | 1.25 | 0.90 | 0.221 | 9 |
| Winnipeg | 145 | 152 | | -11% | 1.60 | 0.97 | 1.61 | 0.209 | 10 |
| Halifax | 116 | 121 | | -2% | 2.86 | 1.74 | 0.34 | 0.396 | 2 |
| Saskatoon | 84 | 93 | | -33% | 1.83 | 1.11 | 12.83 | 0.391 | 4 |
| Moncton | 15 | 15 | | N/C | N/C | N/C | N/C | N/C | N/C |
| Charlottetown | 9 | 9 | | N/C | N/C | N/C | N/C | N/C | N/C |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, flow of technological property (Flow of IP), growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among cities.
Impact indicators are not calculated for entities with fewer than 30 full patents with a relative impact score. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).
Source: Computed by Science-Metrix using USPTO data from PatentsView.

### 3.2.7 Canada's technological performance by technological domain and field at USPTO

In this subsection, the performance of Canada and its provinces and territories is analyzed by technological field. The patent classification used for this project lists 5 main domains (including an "other fields" domain) and 35 fields. Patents have been fractioned further according to these multiple classifications so that the sum across domain and fields add up. Details about this classification are available in the methodology (Section 5).

#### Canada

Electrical Engineering patents represent the highest percent of Canada's patent portfolio (23,000 patents via fractional counting; 39.2%; Table XVIII). However, this was the only technological domain that had a decline in growth rate during the period (GR = 0.81; GI = 0.72). Electrical Engineering is followed by Mechanical Engineering (12,000 patents; 20.5%). Chemistry (8,400 patents; 14.3%) and Instruments (8,600 patents; 14.7%) represent roughly the same proportion of the portfolio. Canada gained 6,400 patents (11.0%) in "Other Fields", which include Civil Engineering, Furniture and Games, and Other Consumer Goods. At the field level, as previously observed, Canada's largest output is observed in Computer Technology (6,700 patents; 11.5%), Digital Communication (6,600 patents; 11.3%). However,

Telecommunication (2,400 patents; 4.2%) represents half as much of the portfolio than it did previously (Telecommunications represented 8.2% of Canada's patent portfolio in the previous report).

Canada's patenting growth ratio varied across domains. Growth rate was consistently positive in the domain of Instruments, ranging from a GR of 1.28 for Analysis of Biological Materials to 1.47 in Medical Technology. All the fields within this domain exceeded global growth rates except for the area of Control (GI = 1.0). With the exception of Textile and Paper Machines (GR = 0.79) and Machine Tools (GR = 0.99), all fields of Mechanical Engineering had positive growth over the period. However, only three fields of Mechanical Engineering exceeded the global growth rate: Engines, Pumps, Turbines (GR = 1.72; GI = 1.50), Mechanical Elements (GR = 1.23; GI = 1.07), and Transport (GR = 1.34; GI = 1.01). Chemistry and Electrical Engineering both had a wide range in growth represented among their fields. The highest growth ratio among all fields was seen in Food Chemistry (domain of Chemistry), which had a GR of 2.47 and exceeded global growth by 89% (GI = 1.89). Along with Food Chemistry, three fields in Chemistry had a high GR: Surface Technology, Coating (GR = 1.37; GI = 1.15), Chemical Engineering (GR = 1.34; SI = 1.13), and Environmental Technology (GR = 1.26; GI = 1.19). All other fields in Chemistry had a GR close to 1. Four of the five lowest growth rates were in fields within the Electrical Engineering domain. Within this domain, only IT Methods for Management, which ranked 3rd in terms of GR, significantly outpaced global growth (GR = 1.47; GI = 1.16).

Trends in specialization index largely mirrored trends in GR, with five of the top ten highest SI scores seen in the fields of Mechanical Engineering. Fields within Electrical Engineering and Chemistry tended to have a lower SI. The fields of Chemistry that had the highest SI also had high GR: Chemical Engineering (SI = 1.35) and Environmental Technology (SI = 1.60). All fields of Electrical Engineering had an SI below 1 except for three fields: Digital Communication (SI = 1.21), IT Methods for Management (SI = 1.20), and Telecommunications (SI = 1.17). Two of the three highest SI scores were within the Other Fields domain: Civil Engineering had the highest SI (SI= 2.80) while Furniture, Games had the third highest SI (SI = 1.64). Both fields also had higher GR during the period.

## Table XVIII Technological performance of Canada by field (2012–2023) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All fields** | **58,496** | **59,825** | | **1.00** | **-28%** | **1.05** | **0.93** | **1.00** |
| Chemistry | 8,383 | 11,424 | | 1.05 | -23% | 1.10 | 1.08 | 0.98 |
| Basic materials chemistry | 815 | 1,706 | | 1.00 | -33% | 1.05 | 1.10 | 0.94 |
| Biotechnology | 1,198 | 2,575 | | 1.16 | -16% | 0.93 | 0.83 | 0.86 |
| Chemical engineering | 1,209 | 2,682 | | 1.35 | -19% | 1.34 | 1.13 | 1.01 |
| Environmental technology | 805 | 1,610 | | 1.60 | -10% | 1.26 | 1.19 | 0.97 |
| Food chemistry | 345 | 681 | | 1.00 | -65% | 2.11 | 1.89 | 0.93 |
| Macromolecular chemistry, polymers | 268 | 706 | | 0.48 | -52% | 1.07 | 1.12 | 1.30 |
| Materials, metallurgy | 556 | 1,179 | | 0.98 | -16% | 1.19 | 1.01 | 1.20 |
| Micro-structural and nano-technology | 161 | 466 | | 0.73 | -19% | 0.87 | 1.29 | 1.61 |
| Organic fine chemistry | 771 | 1,776 | | 0.82 | -16% | 0.95 | 1.16 | 1.09 |
| Pharmaceuticals | 1,778 | 3,584 | | 1.22 | -11% | 0.94 | 0.95 | 0.86 |
| Surface technology, coating | 476 | 1,086 | | 0.77 | -21% | 1.37 | 1.15 | 0.95 |
| Electrical engineering | 22,937 | 27,087 | | 0.83 | -39% | 0.81 | 0.72 | 0.99 |
| Audio-visual technology | 1,947 | 3,710 | | 0.68 | -27% | 0.84 | 0.83 | 1.13 |
| Basic communication processes | 527 | 1,041 | | 0.63 | -57% | 0.54 | 0.62 | 1.22 |
| Computer technology | 6,701 | 11,172 | | 0.81 | -45% | 1.00 | 0.80 | 0.97 |
| Digital communication | 6,606 | 10,155 | | 1.21 | -39% | 0.62 | 0.53 | 0.92 |
| Electrical machinery, apparatus, energy | 2,538 | 4,238 | | 0.70 | -28% | 1.14 | 1.00 | 1.04 |
| IT methods for management | 1,575 | 3,093 | | 1.20 | -27% | 1.47 | 1.16 | 0.85 |
| Semiconductors | 573 | 1,043 | | 0.18 | -23% | 1.03 | 1.03 | 1.07 |
| Telecommunications | 2,469 | 4,647 | | 1.17 | -37% | 0.41 | 0.46 | 1.00 |
| Instruments | 8,605 | 13,700 | | 0.86 | -25% | 1.39 | 1.20 | 0.96 |
| Analysis of biological materials | 485 | 1,257 | | 1.40 | -17% | 1.28 | 1.09 | 0.79 |
| Control | 1,424 | 3,110 | | 1.10 | -24% | 1.43 | 1.00 | 1.11 |
| Measurement | 2,552 | 4,889 | | 0.99 | -26% | 1.31 | 1.07 | 1.18 |
| Medical technology | 3,321 | 5,062 | | 0.93 | -15% | 1.47 | 1.24 | 0.69 |
| Optics | 823 | 1,592 | | 0.38 | -50% | 1.40 | 1.46 | 1.23 |
| Mechanical engineering | 11,986 | 16,160 | | 1.28 | -13% | 1.27 | 1.06 | 1.09 |
| Engines, pumps, turbines | 1,912 | 2,865 | | 1.42 | -12% | 1.72 | 1.50 | 1.21 |
| Handling | 1,353 | 2,314 | | 1.36 | -13% | 1.20 | 0.96 | 1.24 |
| Machine tools | 840 | 1,436 | | 1.02 | -14% | 0.99 | 0.92 | 0.95 |
| Mechanical elements | 1,545 | 2,910 | | 1.19 | -17% | 1.23 | 1.07 | 1.04 |
| Other special machines | 2,354 | 3,685 | | 1.75 | -8% | 1.12 | 0.89 | 0.80 |
| Textile and paper machines | 242 | 544 | | 0.37 | -40% | 0.79 | 0.96 | 1.04 |
| Thermal processes and apparatus | 747 | 1,337 | | 1.50 | -11% | 1.28 | 0.90 | 1.09 |
| Transport | 2,994 | 4,586 | | 1.23 | -13% | 1.34 | 1.01 | 1.17 |
| Other fields | 6,422 | 9,024 | | 2.00 | -16% | 1.24 | 1.05 | 0.95 |
| Civil engineering | 3,590 | 5,029 | | 2.80 | -16% | 1.23 | 1.05 | 0.85 |
| Furniture, games | 1,797 | 2,793 | | 1.64 | -17% | 1.31 | 1.16 | 1.05 |
| Other consumer goods | 1,035 | 1,768 | | 1.23 | -15% | 1.17 | 0.93 | 1.08 |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, specialization index (SI), flow of intellectual property (Flow of IP), growth rate (GR), growth index relative to the world (GI), average relative citation (ARC).
Impact indicators are not calculated for entities with fewer than 30 full patents with a relative impact score. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).
The scale in the trends are not the same across fields.

Source: Computed by Science-Metrix using USPTO data from PatentsView.

Canada's deficit in terms of invention and ownership of patents is presented in all technological fields with Flow of IP ranging from -8% (Other Special Machines) to -65% (Food Chemistry).

No clear trends were evident in Canada's ARC scores across technological fields, which ranged from 0.69 (Medical Technology) to 1.61 (Micro-Structural and Nano-Technology). Fields with ARC in the range of 1.20-1.30 were distributed across Chemistry (Macromolecular Chemistry, Polymers, ARC = 1.30; Materials, Metallurgy, ARC = 1.20), Mechanical Engineering (Handling, ARC = 1.24; Engines, pumps, Turbines, ARC = 1.21), and Instruments (Optics, ARC = 1.23).

### Canada's provinces and territories (USPTO)

The following is a summary of the most significant results for each province in bullet form ordered by geographical location from west to east. The patenting behaviour of Prince Edward Island and the territories are not discussed further since they produced very few patents, which were insufficient to calculate performance indicators in all domains of technology. Note that only the performance at the USPTO will be presented in the report, both to keep the report at a reasonable length, and also because levels of output at the EPO for most provinces are much lower, leading to low counts at the domain and field levels and, thus, indicators more prone to fluctuations.

- British Columbia (Table XIX) is highly specialized in all fields of the Other Fields category (Civil Engineering, SI = 2.31; Furniture and Games, SI = 2.27; and Other Consumer Goods, SI = 2.09), and has increased its specialization in these fields since the last report. Its output grew over the study period in all domains except for Electrical Engineering. Its highest growth is observed in Instruments (GR = 1.49), both in absolute terms and compared to the growth at the world level (GI = 1.28). Its highest impact is observed in Chemistry (ARC = 1.67), driven in large parts by the fields of Micro-structural and Nano-technology (ARC = 2.98) and Organic Fine Chemistry (2.38).

Table XIX Technological performance of British Columbia by technological domain (2012–2023) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All domains** | **6,745** | **7,030** | | **1.00** | **-36%** | **1.30** | **1.15** | **1.23** |
| Chemistry | 1,416 | 1,936 | | 1.54 | -7% | 1.34 | 1.30 | 1.67 |
| Electrical engineering | 2,064 | 2,685 | | 0.65 | -57% | 1.26 | 1.13 | 1.34 |
| Instruments | 1,171 | 1,874 | | 1.02 | -30% | 1.49 | 1.28 | 0.97 |
| Mechanical engineering | 1,232 | 1,819 | | 1.14 | -18% | 1.25 | 1.04 | 1.02 |
| Other fields | 831 | 1,189 | | 2.24 | -13% | 1.14 | 0.97 | 0.98 |

Note: The trend charts are not comparable between domains. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using data from PatentsView

- Alberta (Table XX) is very highly specialized in Other Fields (SI = 3.38) due to Civil Engineering (SI = 11.84), further specializing in the categories compared to the previous report. Alberta also remained well specialized in the domain of Chemistry (SI = 1.50), due to the fields of Basic Materials Chemistry (SI = 4.01), Chemical Engineering (SI = 2.80) and Environmental Technology (SI = 2.68). It grew in all domains, particularly in Other Fields (GR = 1.43), also the domain with

the highest impact (ARC = 1.21). Alberta highest impact at the field level is observed in Surface Technology, Coating, under Chemistry (ARC = 2.47).

Table XX Technological performance of Alberta by technological domain (2012–2023) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All domains** | **5,588** | **5,764** | | **1.00** | **-23%** | **1.22** | **1.08** | **0.88** |
| Chemistry | 1,143 | 1,519 | | 1.50 | -22% | 1.12 | 1.09 | 0.76 |
| Electrical engineering | 1,068 | 1,366 | | 0.40 | -32% | 1.14 | 1.02 | 0.95 |
| Instruments | 668 | 1,070 | | 0.70 | -25% | 1.30 | 1.12 | 0.90 |
| Mechanical engineering | 1,044 | 1,542 | | 1.17 | -15% | 1.06 | 0.89 | 1.05 |
| Other fields | 1,654 | 2,189 | | 5.38 | -21% | 1.43 | 1.21 | 0.81 |

Note: The trend charts are not comparable between domains. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using data from PatentsView

- Saskatchewan (Table XXI) grew substantially in Instruments (GR = 2.34) and Electrical Engineering (GR = 2.25), although the actual number of patents is rather low. Saskatchewan is most specialized in Mechanical Engineering (SI = 4.01), further specializing compared to the last report (SI = 2.99) due to the field of Special Machines (SI = 18.98), which account for close to 500 patents, or 44% of all Saskatchewan's patents. Saskatchewan's highest impact was registered in Electrical Engineering (ARC = 1.59), and at the field level, an ARC of 4.27 was reached under Thermal Processes and Apparatus, a field of Mechanical Engineering.

Table XXI Technological performance of Saskatchewan by technological domain (2012–2023) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All domains** | **1,125** | **1,162** | | **1.00** | **-11%** | **1.51** | **1.33** | **1.12** |
| Chemistry | 180 | 253 | | 1.18 | -43% | 1.11 | 1.08 | 0.89 |
| Electrical engineering | 69 | 115 | | 0.13 | -18% | 2.25 | 2.01 | 1.59 |
| Instruments | 90 | 166 | | 0.47 | -4% | 2.34 | 2.01 | 0.99 |
| Mechanical engineering | 723 | 847 | | 4.01 | 4% | 1.56 | 1.30 | 1.20 |
| Other fields | 62 | 99 | | 1.01 | -20% | 0.91 | 0.77 | 0.72 |

Note: The trend charts are not comparable between domains. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using data from PatentsView

- Manitoba (Table XXII) is highly specialized in Other Fields (SI = 2.59), Mechanical Engineering (SI = 2.15) and Chemistry (SI = 1.70), although the impact in these domains registers median or little impact. It grew substantially in Electrical Engineering (GR = 1.87, GI = 1.67), the only domain for which growth was observed. However, Manitoba remains under specialized in this

domain (SI = 0.22). Manitoba's strongest specialization at the field level is observed in Food Chemistry (SI = 7.17, 40 patents).

Table XXII Technological performance of Manitoba by technological domain (2012–2023) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All domains** | **970** | **1,020** | | **1.00** | **-8%** | **0.97** | **0.86** | **0.77** |
| Chemistry | 225 | 306 | | 1.70 | -14% | 0.87 | 0.85 | 0.61 |
| Electrical engineering | 100 | 158 | | 0.22 | -15% | 1.87 | 1.67 | 0.77 |
| Instruments | 167 | 259 | | 1.01 | -13% | 0.88 | 0.76 | 0.88 |
| Mechanical engineering | 333 | 449 | | 2.15 | -2% | 0.91 | 0.77 | 0.86 |
| Other fields | 138 | 200 | | 2.59 | 2% | 0.91 | 0.77 | 0.79 |

Note: The trend charts are not comparable between domains. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using data from PatentsView

- Ontario (Table XXIII) is most specialized in Other Fields (SI = 1.42) due to Furniture, Games (SI = 1.69) and Civil Engineering (SI = 1.46). Higher specialization in Other Fields came mostly from Furniture, Games, as a decrease in specialization was observed in Civil Engineering compared to the last report. While many fields in Electrical Engineering had grown substantially their output over the previous study period, this time declines were observed in many of these: Digital Communication (GR = 0.49, compared to 4.80), Computer Technology (GR = 0.78, compared to 4.49), Telecommunications (GR = 0.31, compared to 3.48) and Audio-visual Technology (GR = 0.66 compared to 2.77). The highest growth was measured in Instruments (GR = 1.42) and Other Fields (GR = 1.29). Overall, Ontario's output has kept up or grown faster than the world level across all domains except Electrical Engineering (BlackBerry effect), and to a lesser extent Mechanical Engineering (GR = 1.12, GI = 0.94). Ontario's highest impact is measured in Other Fields (ARC = 1.09) and Mechanical Engineering (ARC = 1.08).

Table XXIII Technological performance of Ontario by technological domain (2013–2022) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All domains** | **29,889** | **30,744** | | **1.00** | **-30%** | **0.87** | **0.77** | **0.97** |
| Chemistry | 3,246 | 4,614 | | 0.80 | -32% | 1.12 | 1.10 | 0.89 |
| Electrical engineering | 15,879 | 18,133 | | 1.12 | -34% | 0.63 | 0.57 | 0.92 |
| Instruments | 4,113 | 6,691 | | 0.81 | -25% | 1.42 | 1.22 | 1.01 |
| Mechanical engineering | 4,227 | 5,969 | | 0.88 | -28% | 1.12 | 0.94 | 1.08 |
| Other fields | 2,339 | 3,401 | | 1.42 | -10% | 1.29 | 1.09 | 1.09 |

Note: The trend charts are not comparable between domains. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using data from PatentsView

- After the general decrease observed in Quebec's patenting activity in the previous report, the province has seen growth across all domains, except Chemistry where its output remained mostly stable (GR =0.98) (Table XXIV). Highest growth was measured in Mechanical Engineering (GR = 1.71), Instruments (GR = 1.45) and Electrical Engineering (GR = 1.42). Quebec is highly specialized in Mechanical Engineering, drastically increasing its SI in this domain (GR = 2.19, compared to 1.36). The province is also specialized in Other Fields (SI = 1.52). Its patents are most impactful in Mechanical Engineering (ARC = 1.15), the only domain where it scores above the world level. Quebec's highest specialization at the field level is in Engines, Pumps, Turbines, under Mechanical Engineering (SI = 5.03). It is also the fields which experienced the strongest growth (GR = 2.35), and one of Quebec's most impactful areas (ARC = 1.21). Semiconductors, as key strategic technology, is the field where the province is most impactful (ARC = 1.53), but it is not specialized at all in this field (SI = 0.11).

Table XXIV Technological performance of Quebec by technological domain (2012–2023) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All domains** | **10,051** | **10,395** | | **1.00** | **-26%** | **1.41** | **1.24** | **0.94** |
| Chemistry | 1,561 | 2,198 | | 1.14 | -17% | 0.98 | 0.96 | 0.78 |
| Electrical engineering | 2,441 | 3,206 | | 0.51 | -52% | 1.42 | 1.27 | 0.86 |
| Instruments | 1,675 | 2,712 | | 0.98 | -27% | 1.45 | 1.25 | 0.87 |
| Mechanical engineering | 3,520 | 4,446 | | 2.19 | 9% | 1.71 | 1.43 | 1.15 |
| Other fields | 840 | 1,216 | | 1.52 | -28% | 1.11 | 0.94 | 0.76 |

Note: The trend charts are not comparable between domains. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using data from PatentsView

- New Brunswick (Table XXV) acquired about 400 patents between 2012 and 2023. The indicators for each domain should consequently be interpreted with caution. Nevertheless, New Brunswick is well specialized in the Other Fields (SI = 2.69), driven by its high specialization in Civil Engineering (SI = 4.03). New Brunswick grew only in Chemistry (GR = 1.55) and Other Fields (GR = 1.14), but its output is relatively in these to begin with. New Brunswick's impact is above world level only in Electrical Engineering (ARC = 1.05).

Table XXV Technological performance of New Brunswick by technological domain (2012–2023) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All domains** | **415** | **427** | | **1.00** | **-6%** | **1.00** | **0.89** | **0.75** |
| Chemistry | 57 | 77 | | 1.00 | 20% | 1.55 | 1.52 | 0.72 |
| Electrical engineering | 61 | 83 | | 0.31 | -56% | 0.91 | 0.81 | 1.05 |
| Instruments | 161 | 206 | | 2.27 | 12% | 0.92 | 0.79 | 0.59 |
| Mechanical engineering | 75 | 106 | | 1.13 | 13% | 0.84 | 0.70 | 0.71 |
| Other fields | 61 | 101 | | 2.69 | 31% | 1.14 | 0.97 | 0.94 |

Note: The trend charts are not comparable between domains. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using data from PatentsView

- Nova Scotia acquired close to 1,000 new patents (Table XXVI). Nova Scotia grew most in Electrical Engineering (GR = 4.63), a continued, stronger growth from the previous report (GR = 1.69), which happens remain its most impactful field (ARC = 1.69). This strong increase shifted the specialization profile of the province, which was not specialized in the previous study period, but now is (SI = 1.17, compared to 0.68), with this domain now being its only area of specialization. Among fields with more than 50 patents, Nova Scotia is still most specialized in Computer Technology (SI = 1.87, 250 patents).

Table XXVI Technological performance of Nova Scotia by technological domain (2012–2023) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All domains** | **925** | **956** | | **1.00** | **46%** | **2.67** | **2.36** | **1.44** |
| Chemistry | 115 | 164 | | 0.92 | -18% | 2.16 | 2.11 | 1.25 |
| Electrical engineering | 512 | 562 | | 1.17 | 154% | 4.63 | 4.14 | 1.69 |
| Instruments | 138 | 215 | | 0.88 | -11% | 2.22 | 1.90 | 1.14 |
| Mechanical engineering | 110 | 168 | | 0.74 | 20% | 1.00 | 0.84 | 1.16 |
| Other fields | 47 | 75 | | 0.93 | 8% | 0.79 | 0.67 | 0.67 |

Note: The trend charts are not comparable between domains. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using data from PatentsView

- Newfoundland produced slightly above 100 patents (Table XXVII). For this reason, indicators could only be computed for three domains. Among these, Newfoundland is most specialized in Instruments (SI = 1.61), a continuation from the previous report. It maintained strong growth in Electrical Engineering (GR = 3.08, compared to 4.63) but, once again, technological output was very low to begin with.

Table XXVII Technological performance of Newfoundland by technological domain (2012–2022) (USPTO)

| Field | Technological output | | | | | | | Impact |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | SI | Flow of IP | GR | GI | ARC |
| **All domains** | **128** | **132** | | **1.00** | **-23%** | **1.49** | **1.32** | **0.98** |
| Chemistry | 11 | 15 | | N/C | N/C | N/C | N/C | N/C |
| Electrical engineering | 49 | 64 | | 0.81 | -45% | 3.08 | 2.75 | 1.07 |
| Instruments | 35 | 51 | | 1.61 | 21% | 0.76 | 0.66 | 1.18 |
| Mechanical engineering | 24 | 35 | | 1.18 | 0% | 0.95 | 0.79 | 0.94 |
| Other fields | 9 | 12 | | N/C | N/C | N/C | N/C | N/C |

Note: The trend charts are not comparable between domains. The colour grading is indicative of the level of growth for the GR (from white to dark green for an increase and from white to dark red for a decrease) and relative to the world or Canadian level for the other indicators (from white to dark green when above and from white to dark red when below the world or Canadian level). N/C: not calculated.
Source: Computed by Science-Metrix using data from PatentsView

As a general conclusion, all provinces are well specialized in the fields Analysis of Biological Materials, Civil Engineering, Environmental Technology, Furniture, Games, Handling, Other Special Machines, and Thermal Processes and Apparatus.

## 3.3 Technological performance of Canada's leading organizations

### Most publishing Canadian organizations (USPTO)

This subsection explores the technological production and impact of Canada's institutions, which gained the largest number of patents between 2012 and 2023. The top 50 institutions are presented in Table XXVIII.

As observed in the previous study, BlackBerry dominates the Canadian landscape in terms of patent ownership, acquiring 7,400 patents, which represents 12.7% of Canada's USPTO patent portfolio. Despite retaining the top rank in terms of share of patents by ten percentage points, Blackberry's share of Canada's patent portfolio has declined since the previous report and its GR has been significantly lower than that of Canada overall (BlackBerry GR = 0.23; Canada GR = 1.05). Nortel, having become defunct in 2013, no longer appears on the list. Pratt & Whitney follows Blackberry in 2nd place with 1,624 new patents. At 2.8% of Canada's patent portfolio, Pratt & Whitney are of note because of their high growth over the period (GR = 2.74; GI = 2.42). Magna, OpenText, University of Toronto, and ATI Technologies each contribute just over 1% of Canada's patent portfolio. All other organizations among the top 50 generated less than 1% of Canada's patent portfolio. A total of seven universities made the top 50; the ones with the most patents being the University of Toronto (5th place; 648 patents), the University of British Columbia (11th place; 335 patents), McGill University (18th place; 194 patents), and University of Alberta (19th place; 187 patents). The University of Ottawa and Université de Montréal, which were among the top 50 organizations in the previous study, no longer appear in the list. New to the list were two banks: TD Bank (498 patents) and Royal Bank of Canada (135 patents), which also had very high growth during the period (TD Bank GR = 23.90, GI = 21.15; Royal Bank of Canada GR = 32.75; GI = 28.98). Aside from a public utility (Hydro-Québec 140 patents; stable growth over the period with GR = 1.05) and NRC, no other government agency or organization made the top 50.

# Table XXVIIITechnological performance of top patenting Canadian organizations (2012–2023) (USPTO)

| Canadian organization | Technological output | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | GR | GI | ARC | Score | Rank |
| **Canada** | **58,496** | **59,825** | | **1.05** | **0.93** | **1.00** | - | - |
| BlackBerry | 7,404 | 7,437 | | 0.23 | 0.20 | 0.78 | 0.431 | 2 |
| Pratt & Whitney | 1,624 | 1,631 | | 2.74 | 2.42 | 1.07 | 0.143 | 7 |
| Magna | 720 | 721 | | 1.28 | 1.14 | 1.25 | 0.096 | 11 |
| OpenText | 654 | 654 | | 10.08 | 8.92 | 1.75 | 0.154 | 6 |
| University of Toronto | 648 | 761 | | 1.48 | 1.31 | 0.71 | 0.068 | 19 |
| ATI Technologies | 600 | 718 | | 0.88 | 0.78 | 0.48 | 0.052 | 27 |
| TD Bank | 498 | 498 | | 23.90 | 21.15 | 0.73 | 0.157 | 5 |
| CNH Industrial | 495 | 499 | | 1.59 | 1.41 | 0.95 | 0.072 | 17 |
| Conversant Intellectual Property Management | 397 | 397 | | 0.16 | 0.14 | 0.65 | 0.046 | 29 |
| Omachron | 371 | 371 | | 7.43 | 6.58 | 1.03 | 0.093 | 13 |
| University of British Columbia | 335 | 385 | | 1.16 | 1.02 | 1.09 | 0.067 | 20 |
| Bombardier Recreational Products | 322 | 323 | | 1.57 | 1.39 | 1.50 | 0.087 | 14 |
| IGNIS Innovation | 273 | 273 | | 1.27 | 1.13 | 1.72 | 0.094 | 12 |
| NRC Canada - National Research Council | 254 | 304 | | 0.76 | 0.68 | 0.71 | 0.044 | 32 |
| WiLAN | 211 | 211 | | 0.21 | 0.19 | 0.84 | 0.045 | 31 |
| Avigilon | 206 | 206 | | 1.99 | 1.76 | 1.04 | 0.062 | 23 |
| Bombardier | 197 | 203 | | 5.55 | 4.91 | 0.78 | 0.064 | 22 |
| McGill University | 194 | 233 | | 0.82 | 0.72 | 0.69 | 0.040 | 33 |
| University of Alberta | 187 | 218 | | 0.73 | 0.65 | 0.30 | 0.021 | 45 |
| D-Wave Systems | 186 | 186 | | 1.32 | 1.17 | 2.73 | 0.136 | 8 |
| ViXS Systems | 178 | 178 | | 0.05 | 0.04 | 0.45 | 0.024 | 43 |
| Geotab | 169 | 169 | | 17.78 | 15.73 | 2.37 | 0.189 | 4 |
| Mitel Networks | 163 | 163 | | 0.61 | 0.54 | 0.52 | 0.030 | 39 |
| Husky Injection Molding Systems | 153 | 153 | | 0.65 | 0.57 | 0.72 | 0.038 | 34 |
| BCE | 153 | 153 | | 0.56 | 0.50 | 0.30 | 0.018 | 46 |
| Accedian Networks | 151 | 151 | | 1.60 | 1.42 | 0.39 | 0.027 | 42 |
| McMaster University | 144 | 160 | | 1.44 | 1.27 | 1.22 | 0.064 | 21 |
| AI Incorporated | 142 | 142 | | 70.00 | 61.94 | 5.96 | 0.578 | 1 |
| Shopify | 141 | 141 | | N/C | N/C | 0.94 | N/C | N/C |
| Hydro-Québec | 140 | 158 | | 1.05 | 0.93 | 0.46 | 0.027 | 41 |
| Guest-Tek | 138 | 139 | | 0.83 | 0.74 | 1.12 | 0.057 | 25 |
| Medtronic CryoCath | 136 | 136 | | 0.84 | 0.74 | 0.54 | 0.030 | 38 |
| Royal Bank of Canada | 135 | 135 | | 32.75 | 28.98 | 1.09 | 0.192 | 3 |
| Dana Holding | 133 | 133 | | 1.94 | 1.72 | 1.41 | 0.075 | 16 |
| Cooledge Lighting | 127 | 127 | | 0.38 | 0.34 | 1.58 | 0.076 | 15 |
| Kardium | 126 | 126 | | 2.00 | 1.77 | 1.03 | 0.057 | 24 |
| Evolution Engineering Inc. | 120 | 120 | | 2.33 | 2.06 | 0.58 | 0.037 | 35 |
| Université Laval | 118 | 140 | | 0.90 | 0.80 | 0.54 | 0.029 | 40 |
| 2236008 Ontario Inc. | 118 | 143 | | 0.61 | 0.54 | 0.69 | 0.035 | 37 |
| North Inc. | 115 | 115 | | N/C | N/C | 1.21 | N/C | N/C |
| Trudell Medical | 113 | 115 | | 1.14 | 1.01 | 0.95 | 0.049 | 28 |
| Queen's University | 110 | 121 | | 1.36 | 1.20 | 1.07 | 0.055 | 26 |
| Litens Automotive | 110 | 110 | | 0.69 | 0.61 | 1.45 | 0.070 | 18 |
| Titan Medical Inc. | 108 | 108 | | 6.71 | 5.94 | 1.98 | 0.120 | 10 |
| Smart Technologies | 106 | 106 | | 0.08 | 0.07 | 0.51 | 0.024 | 44 |
| Oracle | 105 | 105 | | N/C | N/C | 1.36 | N/C | N/C |
| Westport Fuel Systems | 95 | 99 | | 1.00 | 0.88 | 0.90 | 0.045 | 30 |
| Iogen | 91 | 92 | | 0.86 | 0.76 | 2.75 | 0.130 | 9 |
| UTI - University Technologies International | 90 | 98 | | 1.45 | 1.29 | 0.67 | 0.036 | 36 |
| Synaptive Medical Inc. | 89 | 89 | | N/C | N/C | 0.61 | N/C | N/C |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among selected organizations.
indicators are not calculated for entities with fewer than 30 full patents. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).
The scale in the trends is not the same across countries.

Source: Computed by Science-Metrix using data from PatentsView

Although patenting activities are usually quite sporadic within institutions, in some cases, clear trends are apparent. For example, as mentioned above, BlackBerry has seen a considerable decline in patenting activities over the period while Pratt & Whitney has seen significant growth. For AI Incorporated, the GR of 70.00 can be explained by the fact that it was founded in 2016 so all but two of its patents were granted in the latter part of the period. This is not the case for OpenText, which was founded in 1991, and saw a rapid increase in granted patents in the latter half of the period, resulting in a GR of 10.08 (GI = 8.92). For all organizations that saw high growth rates, further investigation is needed to determine whether the increase was the result of an increase in acquisitions, increased patenting activities resulting from in-house innovations or other reasons.

The ARC of the top Canadian institutions ranged from 5.96 (AI Incorporated) to 0.30 (University of Alberta and BCE), indicating that not all organizations have the same level of impact. Following AI Incorporated, the most impactful inventions belong to Iogen (ARC = 2.75), D-Wave Systems (ARC = 2.73), and Geotab (ARC = 2.37). Half of the institutions had an ARC below the world average and five performed on par with the global standard.

According to the composite indicator, AI Incorporated's high growth and ARC ranks it in 1st place, highlighting its recent emergence in the U.S. market and the relevance of its patents. BlackBerry occupies 2nd place, due to its high output. Royal Bank of Canada and TD Bank rank 3rd and 5th, respectively and mostly because of the GR, although their score was less than half that of BlackBerry.

### Most publishing Canadian organizations (EPO)

Table XXIX presents the leading Canadian organization in the European market, based on the number of granted patents at the EPO. Similarly to the USPTO data, BlackBerry leads the way, with close to 4,000 patents, which represents 31% of all Canadian patents, a share two and a half times the one observed in the U.S. market. Furthermore, Blackberry's patent output at EPO has been growing (GR = 1.13), although much less than the Canadian level (GR = 1.51), but still indicating increased patenting activity in this market compared to the U.S. market where a strong decline was measured (GR = 0.23). As Blackberry's output at both offices appear to align in recent years, this seems to indicate a redefining of BlackBerry patenting strategies, where less patents are filed in the U.S. market, and those that are end up with active patents in both markets.

Pratt and Whitney again ranks 2nd at the EPO, with 375 new patents (2.9%), followed by Magna (246 patents, 1.9%), the University of Toronto (189 patents, 1.5%) and Husky Injection Molding Systems (137 patents, 1.1%). In comparison to the U.S market, many fewer patents are granted to Canadian organizations at the EPO, with only 34 organizations with 30 or more new patents. In addition, only seven academic institutions appear among the top 50, with the University of Toronto, through the University Health Network, leading with 189 patents as previously mentioned, followed by the University of British Columbia (79 patents), McGill University (36 patents), the University of Alberta (35 patents), Université Laval (32 patents), Université de Montréal (26 patents) and McMaster University (23 patents).

The strongest growth in the European market is observed for Bombardier (GR = 26.20), with the company not patenting that much in this market prior to 2014. 2236008 Ontario Inc. stands at 2nd (GR = 4.88, but entity is now inactive), Atomic Energy of Canada (GR = 3.62), Trudell Medical (GR = 3.17)

and Pratt & Whitney (GR = 2.88). All of these except Pratt & Whitney present with relatively low numbers of patents, in the 30–80 patent range over the full period. The highest impact was measured for Arbutus Biopharma (ARC = 3.58), Litens Automative (ARC = 1.92), Westport Fuel Systems (ARC = 1.83) and Multimatic (ARC = 1.69).

According to the composite indicator, BlackBerry ranked 1st, followed by Bombardier and Arbutus Biopharma. Litens Automotive and Westport Fuel Systems ranked 4th and 5th respectively because of their growth and impact.

Notable organizations appearing among the top patenting entities at the EPO that were not among leading actors at the USPTO include Mold-Masters (2007) (67 patents, 13th) and Nortel Networks in 14th position with 66 patents. In both cases, it is possible that their level of output at the USPTO falls into a similar range, but lower levels at the EPO for Canadian organizations enable these to rank higher, highlighting a strong focus on the European market. The Canadian Blood Services, with 26 patents, ranks 40th, standing out as a non-profit with a substantial number of patents in Europe.

# Table XXIX Technological performance of top patenting Canadian organizations (2011–2022) (EPO)

| Canadian organization | Technological output | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|
| | Frac | Full | Trend (frac) | GR | GI | ARC | Score | Rank |
| **Canada** | **12,931** | **13,324** | | **1.51** | **0.92** | **1.16** | - | - |
| BlackBerry | 4,076 | 4,101 | | 1.13 | 0.69 | 1.04 | 0.500 | 1 |
| Pratt & Whitney | 375 | 385 | | 2.88 | 1.75 | 1.03 | 0.156 | 8 |
| Magna | 246 | 247 | | 2.05 | 1.25 | 0.91 | 0.124 | 13 |
| University of Toronto | 189 | 221 | | 2.45 | 1.49 | 1.68 | 0.187 | 6 |
| Husky Injection Molding Systems | 137 | 137 | | 0.93 | 0.57 | 0.51 | 0.067 | 23 |
| Mitel Networks | 133 | 133 | | 0.99 | 0.60 | 0.05 | 0.029 | 31 |
| NRC Canada - National Research Council | 122 | 134 | | 0.96 | 0.59 | 0.83 | 0.093 | 19 |
| ATI Technologies | 116 | 132 | | 1.29 | 0.78 | 0.23 | 0.046 | 28 |
| University of British Columbia | 79 | 104 | | 1.34 | 0.82 | 0.86 | 0.095 | 16 |
| 2236008 Ontario Inc. | 77 | 93 | | 4.88 | 2.97 | 0.85 | 0.134 | 12 |
| Conversant Intellectual Property Management | 70 | 70 | | 0.09 | 0.06 | 0.67 | 0.064 | 24 |
| Bombardier | 68 | 117 | | 26.20 | 15.95 | 1.16 | 0.404 | 2 |
| Mold-Masters (2007) | 67 | 67 | | 0.56 | 0.34 | 0.20 | 0.030 | 30 |
| Nortel Networks | 66 | 66 | | 0.00 | 0.00 | 0.87 | 0.079 | 21 |
| Litens Automotive | 64 | 64 | | 2.37 | 1.44 | 1.92 | 0.194 | 4 |
| Hydro-Québec | 64 | 76 | | 2.79 | 1.70 | 1.36 | 0.152 | 9 |
| Westport Fuel Systems | 63 | 67 | | 2.82 | 1.72 | 1.83 | 0.192 | 5 |
| Rio Tinto Alcan | 62 | 62 | | 2.15 | 1.31 | 0.58 | 0.079 | 22 |
| Medtronic CryoCath | 51 | 51 | | 2.00 | 1.22 | 0.64 | 0.081 | 20 |
| Trudell Medical | 50 | 52 | | 3.17 | 1.93 | 0.11 | 0.050 | 27 |
| Merck | 45 | 57 | | 0.23 | 0.14 | 0.00 | 0.007 | 33 |
| Atomic Energy of Canada | 37 | 37 | | 3.62 | 2.21 | 0.65 | 0.100 | 15 |
| Arbutus Biopharma | 36 | 40 | | 1.71 | 1.04 | 3.58 | 0.323 | 3 |
| McGill University | 36 | 50 | | 1.68 | 1.02 | 0.85 | 0.094 | 17 |
| University of Alberta | 35 | 43 | | 1.72 | 1.05 | 0.45 | 0.061 | 25 |
| Honeywell | 35 | 35 | | 2.14 | 1.30 | 0.11 | 0.037 | 29 |
| Xenon Pharmaceuticals | 32 | 36 | | 0.26 | 0.16 | 1.58 | 0.138 | 11 |
| Université Laval | 32 | 35 | | 1.86 | 1.13 | 0.40 | 0.058 | 26 |
| Multimatic | 32 | 32 | | 1.52 | 0.93 | 1.69 | 0.162 | 7 |
| IMAX | 31 | 31 | | 0.94 | 0.57 | 0.15 | 0.027 | 32 |
| NovAtel | 31 | 31 | | 2.39 | 1.45 | N/C | N/C | N/C |
| FPInnovations | 30 | 30 | | 1.50 | 0.91 | 0.87 | 0.093 | 18 |
| Sierra Wireless | 30 | 30 | | 2.33 | 1.42 | 1.36 | 0.144 | 10 |
| IGNIS Innovation | 30 | 30 | | 2.00 | 1.22 | N/C | N/C | N/C |
| Bauer Hockey | 29 | 29 | | N/C | N/C | N/C | N/C | N/C |
| Ophardt Hygiene | 29 | 29 | | N/C | N/C | N/C | N/C | N/C |
| Trojan Technologies | 28 | 28 | | N/C | N/C | N/C | N/C | N/C |
| Dirtt Environmental Solutions | 28 | 28 | | N/C | N/C | N/C | N/C | N/C |
| Université de Montréal | 26 | 43 | | 2.60 | 1.59 | 0.98 | 0.114 | 14 |
| Canadian Blood Services | 26 | 26 | | N/C | N/C | N/C | N/C | N/C |
| Bathium | 26 | 27 | | N/C | N/C | N/C | N/C | N/C |
| Bombardier Recreational Products | 25 | 25 | | N/C | N/C | N/C | N/C | N/C |
| Spin Master | 25 | 26 | | N/C | N/C | N/C | N/C | N/C |
| Burcon NutraScience | 24 | 24 | | N/C | N/C | N/C | N/C | N/C |
| Medicago | 24 | 29 | | N/C | N/C | N/C | N/C | N/C |
| WiLAN | 23 | 23 | | N/C | N/C | N/C | N/C | N/C |
| VoiceAge | 23 | 25 | | N/C | N/C | N/C | N/C | N/C |
| Motorola Solutions | 23 | 23 | | N/C | N/C | N/C | N/C | N/C |
| McMaster University | 23 | 28 | | N/C | N/C | N/C | N/C | N/C |
| Hatch | 22 | 22 | | N/C | N/C | N/C | N/C | N/C |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, growth rate (GR), growth index (GI), average relative citation (ARC), composite indicator score and rank among selected organizations.
indicators are not calculated for entities with fewer than 30 full patents. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).
The scale in the trends is not the same across countries.

Source: Computed by Science-Metrix using data from PATSTAT (Fall 2023)

### 3.3.1 Technological domains

This subsection provides an overview of organizations driving patenting metrics within each of the five technological domains. However, because of the lower patenting activity of Canadian organizations at the EPO, the report only presents USPTO data, as indicators for most organizations at the domain level cannot be computed, thus adding little value to the current discussion.

The USPTO data (Table XXX) reveal that the biggest contributor to Canada's very high output in Electrical Engineering is BlackBerry (7,050 Electrical Engineering patents). Blackberry is followed in this domain by organizations that contributed less than one tenth the number of patents: e.g. Open Text (647 patents), ATI Technologies (584 patents) and TD Bank (477 patents). The leader in Mechanical Engineering was Pratt & Whitney, which contributed 1,420 patents in this domain during the period. Other leaders in Mechanical Engineering contributed 300–500 patents: Magna (495 patents), CNH Industrial (424 patents), and Bombardier Recreational Products (303 patents). Universities were the biggest contributors to the domain of Chemistry, with five universities among the top 10 contributors in this domain. University of Toronto (303 Chemistry patents) and University of British Columbia (202 patents) both topped the list of organizations leading in Chemistry and were the only universities to also appear as top contributors to the domain of Instruments. Along with University of Toronto and University of British Columbia, the domain of Instruments had a number of organizations that were also top contributors to other domains. BlackBerry, which leads in Electrical Engineering output also leads in Instruments output (276 Instruments patents) and Pratt & Whitney, which leads in Mechanical Engineering output is a significant contributor to Instrument output (103 Instrument patents). AI Incorporated, which stood out for its high composite score, was among the top 10 contributors to the Other Fields domain with 22 patents.

Table XXX Technological performance top patenting Canadian organizations by technological domain (2012–2023) (USPTO)

| Technological domain | Canadian organization | Technological output | | | | | | Impact | Composite indicator | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Frac | Full | Trend (frac) | SI | GR | GI | ARC | Score | Rank |
| Chemistry | University of Toronto | 303 | 451 | | 3.43 | 1.43 | 1.39 | 0.64 | 0.466 | 2 |
| | University of British Columbia | 202 | 274 | | 4.44 | 0.86 | 0.83 | 1.05 | 0.416 | 4 |
| | NRC Canada - National Research Council | 152 | 232 | | 4.41 | 0.59 | 0.58 | 0.78 | 0.353 | 6 |
| | University of Alberta | 114 | 166 | | 4.50 | 0.62 | 0.60 | 0.25 | 0.301 | 8 |
| | McGill University | 93 | 153 | | 3.52 | 0.74 | 0.72 | 0.47 | 0.248 | 10 |
| | Arbutus Biopharma | 85 | 89 | | 7.21 | 0.75 | 0.73 | 5.86 | 0.587 | 1 |
| | Ionen | 80 | 91 | | 6.47 | 0.86 | 0.84 | 2.84 | 0.444 | 3 |
| | Apotex | 67 | 67 | | 7.35 | 0.91 | 0.89 | 0.46 | 0.384 | 5 |
| | Omachron | 61 | 110 | | 1.20 | 18.18 | 17.74 | 0.92 | 0.327 | 7 |
| | McMaster University | 60 | 87 | | 3.08 | 3.42 | 3.34 | 1.24 | 0.254 | 9 |
| Electrical Engineering | BlackBerry | 7,050 | 7,298 | | 2.01 | 0.22 | 0.20 | 0.78 | 0.605 | 1 |
| | OpenText | 647 | 654 | | 2.09 | 10.06 | 8.99 | 1.73 | 0.411 | 3 |
| | ATI Technologies | 584 | 710 | | 2.05 | 0.88 | 0.79 | 0.48 | 0.330 | 5 |
| | TD Bank | 477 | 494 | | 2.02 | 24.34 | 21.75 | 0.73 | 0.423 | 2 |
| | Conversant Intellectual Property Management | 384 | 390 | | 2.04 | 0.16 | 0.14 | 0.66 | 0.322 | 6 |
| | IGNIS Innovation | 261 | 273 | | 2.01 | 1.28 | 1.14 | 1.69 | 0.347 | 4 |
| | WiLAN | 198 | 200 | | 1.98 | 0.22 | 0.20 | 0.88 | 0.311 | 9 |
| | ViXS Systems | 178 | 178 | | 2.10 | 0.05 | 0.04 | 0.45 | 0.316 | 7 |
| | Mitel Networks | 159 | 163 | | 2.06 | 0.61 | 0.54 | 0.50 | 0.313 | 8 |
| | Avigilon | 151 | 189 | | 1.54 | 2.06 | 1.84 | 0.98 | 0.256 | 10 |
| Instruments | BlackBerry | 276 | 534 | | 0.22 | 0.34 | 0.29 | 0.71 | 0.322 | 7 |
| | University of Toronto | 243 | 399 | | 2.20 | 1.36 | 1.17 | 0.79 | 0.394 | 3 |
| | Medtronic CryoCath | 131 | 136 | | 5.65 | 0.77 | 0.66 | 0.49 | 0.442 | 1 |
| | Kardium | 114 | 125 | | 5.28 | 1.99 | 1.71 | 0.94 | 0.419 | 2 |
| | Pratt & Whitney | 103 | 196 | | 0.37 | 3.65 | 3.14 | 0.63 | 0.145 | 9 |
| | Trudell Medical | 92 | 113 | | 4.77 | 1.18 | 1.01 | 0.92 | 0.367 | 4 |
| | Titan Medical Inc. | 74 | 102 | | 4.00 | 8.61 | 7.39 | 1.49 | 0.339 | 5 |
| | University of British Columbia | 73 | 142 | | 1.28 | 1.75 | 1.50 | 0.93 | 0.166 | 8 |
| | Synaptive Medical Inc. | 69 | 87 | | 4.57 | N/C | N/C | 0.59 | N/C | N/C |
| | IGT Canada Solutions UCL | 65 | 79 | | 4.76 | 1.26 | 1.08 | 0.76 | 0.332 | 6 |
| Mechanical Engineering | Pratt & Whitney | 1,420 | 1,558 | | 5.45 | 2.69 | 2.25 | 1.13 | 0.602 | 1 |
| | Magna | 495 | 598 | | 4.30 | 1.07 | 0.90 | 1.24 | 0.350 | 5 |
| | CNH Industrial | 424 | 490 | | 5.35 | 1.42 | 1.19 | 0.96 | 0.374 | 3 |
| | Bombardier Recreational Products | 303 | 312 | | 5.89 | 1.51 | 1.27 | 1.56 | 0.404 | 2 |
| | Husky Injection Molding Systems | 145 | 152 | | 5.92 | 0.61 | 0.51 | 0.75 | 0.330 | 7 |
| | Bombardier | 134 | 188 | | 4.26 | 5.05 | 4.23 | 0.89 | 0.269 | 10 |
| | Litens Automotive | 108 | 110 | | 6.10 | 0.71 | 0.59 | 1.50 | 0.367 | 4 |
| | Dana Holding | 97 | 126 | | 4.57 | 1.69 | 1.41 | 1.30 | 0.284 | 9 |
| | MacDon Industries | 85 | 90 | | 6.20 | 0.88 | 0.73 | 1.03 | 0.345 | 6 |
| | Westport Fuel Systems | 80 | 94 | | 5.24 | 1.25 | 1.04 | 0.91 | 0.292 | 8 |
| Other fields | Omachron | 244 | 326 | | 11.94 | 5.71 | 4.85 | 1.04 | 0.715 | 1 |
| | Magna | 122 | 183 | | 3.07 | 1.93 | 1.64 | 1.55 | 0.301 | 7 |
| | Evolution Engineering Inc. | 89 | 119 | | 13.47 | 2.25 | 1.91 | 0.59 | 0.407 | 5 |
| | Spin Master | 59 | 70 | | 13.05 | 2.46 | 2.09 | 2.88 | 0.460 | 3 |
| | NCS Multistage | 54 | 56 | | 17.36 | 4.35 | 3.69 | 1.16 | 0.526 | 2 |
| | Packers Plus Energy Services | 41 | 41 | | 18.18 | 0.37 | 0.31 | 1.89 | 0.409 | 4 |
| | Oldcastle | 36 | 36 | | 16.98 | 0.34 | 0.29 | 1.12 | 0.351 | 6 |
| | Dirtt Environmental Solutions | 32 | 35 | | 10.66 | 0.71 | 0.60 | 0.72 | 0.239 | 8 |
| | Sport Maska | 26 | 29 | | N/C | N/C | N/C | N/C | N/C | N/C |
| | AI Incorporated | 22 | 52 | | 2.85 | N/C | N/C | 5.68 | N/C | N/C |

Note: Number of fractional and full patents granted, annual trend based on fractional counting, flow of technological property, growth rate (GR), growth index (GI), median relative citation (MRC), composite indicator score.
Indicators are not calculated for entities with fewer than 30 full patents. These are displayed as N/C.
Colour coding indicates performances above (green), on par with (white) or below (red) the world level. The intensity of the gradient represents the level of departure from the world level (darker colours for stronger departure). Colour coding for the GR indicates an increase (green) or decrease (red).
The scale in the trends are not the same across countries.

Source: Computed by Science-Metrix using data from PatentsView.

# 4 Conclusion

This report presents Canada's scientific and technological performance relative to other top performing countries and to the world as a whole, as measured by their contribution to the scientific literature and their new ownership of patents between 2012 and 2023. Over the last decade, Canada's scientific output has been substantial, with 813,000 articles published between 2012 and 2023, positioning it 11th among the world's top publishing countries. This marks a shift from Canada's previous ranking of 7th, largely due to comparatively slower growth in publication rates. Canada's GR of 1.09 reflects a 9% increase in output from 2012–2017 to 2018–2023, comparable to nations like the United States (GR = 1.05) and United Kingdom (GR = 1.05) but lower than global leaders in growth such as Russia (GR = 1.88), China (GR = 1.84), and India (GR = 1.81). Canada's growth index (GI) of 0.80, which is below the worldwide average (GI = 1.37), reflects this trend. Despite this, Canada's research has maintained a notable impact on the global scientific community. It surpassed the global average and ranked 6th among the top 20 countries in all impact-related indicators: ARC, CDI, $HCP_{10\%}$, and FWCS.

Over half of Canada's publications (53.2%) are authored in collaboration with researchers based outside the country. In terms of collaboration partners, Canada's strongest relationship is with the United States. However, Canada's researchers preferentially select partners for collaboration from the United States more frequently than the converse.

Canada's research portfolio demonstrates moderate cross-disciplinarity, with 9.6% of its publications in the top 10% based on disciplinary diversity of references (DDR10), slightly below the expected global level of 10%. However, Canada's DDA10 of 10.9% highlights stronger multidisciplinary collaboration among authors. Overall, Canada's rank in the 11th position based on composite score is a reflection of this relatively lower DDA10 and DDR10. Canada's balanced performance across scientific output, growth ratio, impact, and interdisciplinarity, position it as a notable, if mid-ranked, player in the global scientific landscape.

China and the United States ranked 1st and 2nd, respectively, according to both fractional and full counting of publications, with China surpassing the United States based on output during the period for the first time since the commissioning of these reports. Along with China, India and Russia have also had substantial growth in publication output during the study period. India now ranks 3rd based on fractional counting, up by one position since the last report, while Russia ranks 8th based on fractional counting, up from 14th in the last report. These countries with quickly growing outputs, along with Turkey and Iran, had lower rates of international collaboration, accompanied by weak publication impact. In contrast, the Netherlands, Switzerland and Sweden, which had relatively lower publication output and growth, tended to have very high collaboration rates which was likely responsible for their highly impactful papers.

Consistent with previously observed trends, Canada published nearly one quarter of its articles in Clinical Medicine journals. Information & Communication Technologies, Engineering, and Enabling & Strategic Technologies, which were the next three most represented fields, together represented one quarter of Canada's publication portfolio. Canada exceeded the global average in terms of citation impact in all fields, with exceptionally high citation-based metrics in Information & Communication Technologies and Clinical Medicine. While Canada's output increased in all but a few fields (which had a slight decrease),

Canada did not exceed global growth rates in any fields. Fields that represent areas of high specialization for Canada were Public Health & Health Services and Psychology & Cognitive Sciences. Canada's emerging subfields were mainly in the Health Sciences, with the subfield of Substance Abuse representing Canada's most strongly emerging subfield. In addition to being one of only four subfields that persisted as an emerging subfield since the previous study, Substance Abuse also increased in rank (based on composite indicator score) since the previous study. Clinical Medicine-related topics also had high representation among the most interdisciplinary topics researched in Canada. However, most of the highly interdisciplinary topics were most closely aligned with the Applied Sciences domain.

Ontario was by far the biggest contributor to Canada's total publication output. The next biggest contributors, Quebec and British Columbia, published less than half as much as Ontario. Ontario, Quebec, British Columbia, and Alberta together published Canada's highest impact publications (based on citation impact). High international collaboration rates are often believed to result in a high citation impact. Indeed, British Columbia, which had the highest international co-publication rate, also had the highest ARC and $HCP_{10\%}$. However, although all other provinces in Canada collaborated internationally at a rate close to 50%, they did not achieve a similar citation-based impact. Along with British Columbia, the highest citation-based impact was achieved by Ontario, Quebec, and Alberta. Growth of publication output did not exceed the world's growth level in any provinces and territories. The exception to this was, Newfoundland and Labrador, Prince Edward Island, and the territories, which significantly exceeded the GR of Canada.

Canada ranked 8th in the world in terms of technological production in the U.S. market. However, as observed in the previous study, Canada's growth in patent filing did not exceed the global average. Its patents received a level of citations on par with the global standard. Canada recorded a deficit in terms of ownership of new technology, with a flow of IP of -28%, indicating that more technology has been created by Canadian inventors than is actually owned by Canadian entities. This negative flow of IP resulted in a low composite indicator score for Canada and a rank of 9th place based on this indicator. The United States, which had the highest count of granted patents, a positive flow of IP and a growth rate on par with the global level, retained its position as the leader in technological production.

Removing some of the effect of Canada's tight economic ties to the U.S., data from the EPO helps better contextualize Canada's performance in the patenting landscape. In the European market, Canada ranks 13th in terms of patents, behind a set of European countries which benefited from being benchmarked in their main market. While stronger growth is observed at the EPO, Canada still lags, ranking 14th among leading countries. Canada's flow of IP was again negative at -19%, although slightly less negative than at the USPTO. While Canada's EPO patents were well-cited, with an ARC of 1.16, this was not enough to bring Canada up in the ranking based on the composite indicator; Canada ranked 15th, placing only above Finland, Belgium, Spain, Australia and Taiwan.

Consistent with trends reported in the previous study, Canada's leading sectors in terms of IP (USPTO) were Computer Technology and Digital Communication. However, growth in this area has subsided compared to in the past. In contrast, the domain of Instruments, which showed growth in the past, continued to experience growth. Surprisingly, the field of Food Chemistry had the highest growth ratio,

significantly outpacing global rates of growth (GI = 1.89). No fields of innovation had a positive flow of IP during the period of study.

As noted in the previous study, entities based in Ontario owned half of the new technology created in Canada during the current study period at the USPTO. However, there has been a significant decline in output in Ontario over the period. This decline was likely the driver of Canada's overall decline in growth over that period. Nova Scotia stood apart from the other provinces and territories and took the top rank based on composite indicator score. This was likely due to Nova Scotia having the highest growth, having the highest citation impact and being the only province with a positive flow of IP. At the EPO, similar patterns were observed, but with Ontario increasing its share of patents by about 10 points, and Quebec again ranked 2nd with a share similar to that measured at the USPTO.

At CMA level, Toronto led as an innovation hub in Canada according to USPTO patents, while Kitchener–Cambridge–Waterloo ranked 1st according to patent at the EPO. Kitchener–Cambridge–Waterloo ranked 2nd at the USPTO, while the Greater Toronto area ranked 2nd at the EPO. Montréal, Vancouver and Ottawa followed in this order at both.

At city level, multiple cities presented with strong growth, indicative of the impact of BlackBerry on Canada's performance, and a reminder that a score at the national level may misrepresent the actual dynamism of regions. Overall, in terms of the composite indicator, cities that stood out at the USPTO include Waterloo (1st), Valcourt (2nd), Toronto (3rd), Hampton (4th) and Longueuil (5th). At the EPO, Waterloo again ranked 1st, followed by Renfrew, Saskatoon (Division 11), Longueuil, and Durham.

BlackBerry remains the leader in Canadian patent ownership with 7,400 USPTO patents (12.7% of Canada's patent portfolio), though its growth rate has declined significantly (GR = 0.23) compared to Canada overall (GR = 1.05). The company also ranked first in the European market with 4,000 EPO patents (31% of Canada's patent portfolio). Following BlackBerry, Pratt & Whitney secured the second position with 1,624 USPTO patents (187 EPO patents) and notable growth rates (GR = 2.74 and 5.23, respectively). While seven Canadian universities made the top 50 contributors at the USPTO and four at the EPO, the list also saw new entrants, such as TD Bank and Royal Bank of Canada, both with remarkable growth measured in the U.S. market (GR = 23.9 and GR = 32.75, respectively). ARC values among top institutions showed wide variation, with AI Incorporated leading (ARC = 5.96) and University of Alberta and BCE at the lower end (ARC = 0.30). BlackBerry dominated the Electrical Engineering domain, while Pratt & Whitney led in Mechanical Engineering, and Canadian universities were major contributors in Chemistry.

# 5 Methods

The first step in evaluating the state of S&T is to select appropriate bibliographic and technological databases to perform analyses. The rationale for choosing the Scopus database over other databases for bibliometric analyses is presented in Section 5.1.1, while Section 5.1.2 elaborates on the selection of data coming from the United States Patent and Trademark Office (USPTO) as indexed in PatentsView, and data coming from the European Patent Office, as indexed in the Worldwide Patent Statistical Database (EPO PATSTAT).

Section 5.2 presents the different classification schemes used to classify scientific publications (Section 5.2.1) and patents (Section 5.2.2) into relevant scientific and technological subfields. Section 5.2.3 concludes the classification section by detailing the approach for the delineation of finer scientific areas using a cluster-based approach. Finally, Sections 5.3 and 5.4 present the scientometric and technometric indicators, respectively, that were prepared for this report, and Section 5.5 presents the positional analysis graphs.

## 5.1 Data sources

This section of the report describes the three databases selected for the production of all bibliometric indicators: Scopus for scientometric indicators and PatentsView and PATSTAT for technometric indicators. In both cases, continuity with the previous study prepared in 2016 in support of the CCA's report *Competing in a Global Innovation Economy: The Current State of R&D in Canada* was the most important factor in their selection.

### 5.1.1 Database for scientometric indicators

Science-Metrix used the Scopus database, owned by Elsevier, for the preparation of all scientometric indictors presented in this report and provided in the Excel databook delivered to the CCA. This selection ensured continuity and comparability with the previous update study undertaken in 2016, which also was based on this database. Scopus provides a broad coverage of the scientific literature and indexes some 100 million publications from more than 40,000 peer-reviewed journals of international scope, from over 7,000 publishers, including 27,950 serial titles, 292,000+ books and 11.6+ million conference papers connected through a robust data model including over 94,000 affiliation and 17 million author profiles. Scopus coverage is multilingual and global: approximately 46% of the titles in Scopus are published in languages other than English (or published in both English and another language). In addition, more than half of Scopus content originates from outside North America, representing countries across Europe, Latin America, Africa and the Asia–Pacific region.[18] It was selected for the 2011 and 2016 studies because of its broader coverage of the scientific literature in the Social Sciences & Humanities than its primary comparator, Thomson Reuters' Web of Science, but also because of its thorough indexing of data regarding authors' names and addresses on conference proceedings. This latter feature enables more accurate computation of collaboration statistics. Comprehensive information on articles' authors, their

[18] See www.scopus.com for more details about the database.

affiliations and citations are indexed in Scopus, and all journals have been assigned a unique scientific field by Science-Metrix. The following sections list each scientometric indicator presented in this report. Finally, although most scientometric databases present a bias towards English-speaking and Western countries, Scopus's larger coverage of regional journals results in a lower bias against developing countries such as China and India, which allows for a better positional assessment of various countries regarding production of scientific knowledge.

### 5.1.2 Database for technometric indicators

All of the patent analyses based on USPTO data were prepared using data from the PatentsView database. The database provides details on patents such as full titles and abstracts, the country and state (when available) of the inventors and applicants, as well as names of the inventors and assignees. The database provides information on three classification schemes: the U.S. national classes (the U.S. Patent Classification System (USPC) classes, although these are not available after 2015 as the system is no longer in use), the World Intellectual Property Organization's (WIPO) International Patent Classification (IPC), and the Cooperative Patent Classification (CPC). The CPC was produced in partnership between the USPTO and the European Patent Office (EPO); it replaced the USPC classes after 2015, and the European Classification System (ECLA) after 2012. PatentsView is suitable for the production of technometric data dating from 1976.

PatentsView tables were downloaded and uploaded into the Science-Metrix AWS S3 and Databricks environments. The process is straightforward and does not require any initial treatment because the data are already parsed. Documentation[19] presenting the content of the tables is available on the PatentsView website.

The European Patent Office manages PATSTAT, one of the most comprehensive international patent databases, covering the patent information of about 175 national and regional patent offices. In particular, this database covers two of the most important markets in the world, namely the European and North American markets (through the EPO and the USPTO respectively). PATSTAT is comprehensive, current and accurate. Science-Metrix hosts an in-house version of PATSTAT in the form of SQL relational databases and is licensed to use it to produce technometric data and reports. PATSTAT is frequently used at the international level, with many improvements made to the database each year, providing added-value to the basic data in the database (e.g., coding of private and public sectors, regional coding at the international level for addresses on EPO patents). The city mapping of the EPO patent data is based on such enrichment, which is pushed through REGPAT updates published after a version of the database is released. The PATSTAT edition used for this project is the PATSTAT 2023 Fall edition. Science-Metrix intended to update to PATSTAT 2024 Fall edition for the project, but delays at the European Patent Organization resulted in the database not being available for download until November 2024, which made it impossible to use to meet deadlines associated to the current report.

As discussed above, Science-Metrix selected the same patent office used in the previous assessments, the USPTO, but also provided data at the EPO to better contextualize Canadian innovation from a global

[19] https://patentsview.org/download/data-download-dictionary

perspective. The USPTO and EPO are commonly used to measure inventions. Because the US is the largest market in the world, the most important inventions tend to be patented there, and it is consequently one of the largest registers of patented inventions in the world. Although the USPTO presents an obvious bias towards the US, it is still a potent tool for country-level comparisons. In addition, since the focus is on the analysis of Canada's technological strengths, the USPTO is highly appropriate. The addition of the EPO helps benchmark Canada's position among more countries. While Asian markets are not covered in the analysis because of data limitations in patent databases, adding data from the EPO still helps better position Canada among leading patenting nations as Canada does not benefit from the home-field advantage it holds when the benchmarking is done with only the U.S. market.

## 5.2 Classification scheme

### 5.2.1 Science-Metrix's classification

For continuity purposes, Science-Metrix used its own classification of sciences, which was used in the previous assessment. This journal-based classification presents 5 main domains, 20 fields and 174 subfields of science. This three-level taxonomy of scientific publications was built based on more than 20 years of experience producing scientometric analyses and has been used in hundreds of bibliometric studies undertaken by Science-Metrix over the past six years. The process was also aided by an algorithmic study of interfield citations.

The tens of thousands of journals and proceedings were carefully studied using Elsevier's Scopus database, based on billions of references. These data were used to assign journals to specific subfields through iterative rounds. Each round was followed by an expert review of journal assignments.

Some journals were manually forced into categories; for instance, nanotechnology and biotechnology formed a corpus in large part because of a manual selection of journals. Many journals in education and nursing were also assigned systematically to their respective subfields. Other fields that had great internal coherence and large numbers of journals—which themselves had large number of references—were left to populate themselves more liberally according to the assignment suggested by the algorithm used by Science-Metrix. Details on the classification can be found on Science-Metrix's website.[20]

Science-Metrix's classification has also recently been improved through work for the U.S. National Science Foundation. This work consisted of the reclassification, at paper-level, of multidisciplinary journals such as *Science* and *Nature*, thus providing a more accurate depiction of their content and normalisation of the citation scores of their publications. The work has continued and we could reliably reclassify all publications in Scopus at paper-level, effectively converting Science-Metrix classification from a fully journal-level to a fully paper-level classification system.[21] For the purpose of this project, only general journals are classified at paper level, resulting in a hybrid classification, which mostly relies on the

[20] http://www.science-metrix.com/en/classification

[21] Rivest, M., Vignola-Gagné, E., & Archambault, É. (2021). Article-level classification of scientific publications: A comparison of deep learning, direct citation and bibliographic coupling. *PLoS ONE*, *16*(5 May), p. e0251493. doi:10.1371/journal.pone.0251493.

journal-level mapping, but ensures that papers in the general categories are reclassified where most relevant.[22]

### 5.2.2 World Intellectual Property Organization technology classification

The World Intellectual Property Organization (WIPO) technology classification links the International Patent Classification (IPC) symbols, a widely used system around the world, to 35 fields of technology. This classification stems from efforts by a team at the Fraunhofer Institute for Systems and Innovation Research on behalf of the WIPO, following a need for technical categories to draw comparisons across countries. The first version of the classification is described in a 2008 report available online.[23] Since its inception, this classification has been used by Science-Metrix on multiple projects, including the 2016 report and multiple rounds for the patent indicators of the National Science Foundation Science and Engineering Indicators (SEI 2016, 2018, 2020, 2022 and 2024). One of the most positive factors regarding this classification is that it is freely available, so any team can duplicate findings based on this classification as long as information on IPC patent codes is available. Given the popularity of the classification, it is now integrated into the PATSTAT and PatentsView databases. The latest mapping can be consulted at https://www.wipo.int/ipstats/en/docs/ipc_technology.xlsx.

### 5.2.3 Cluster-based identification of research topics

In addition to the more traditional taxonomies of science based on journals, performing a cluster-based identification of research topics can be useful to highlight emerging structures of the scientific system, as well as connections between disciplines (i.e., interdisciplinarity).

For the current study, Science-Metrix used a clustering provided by SciVal, an Elsevier product. The clustering is based on an approach by Klavans and Boyack to classify Scopus content into research "topics" created via direct citation analysis of publications.[24] Given that the approach generates more than 90,000 topics, further aggregation of topics into clusters is performed, leading to around 1,500 clusters.

Note that because cluster-based classifications are prone to fluctuations over time, cluster-based classifications should only be used to supplement data obtained with more traditional classification as a way to study the dynamics and evolving structure of the scientific system.

## 5.3 Scientometric indicators

This section of the methodology presents the papers-based indicators prepared for this project. These indicators were produced for Canada, its provinces, and the most publishing countries, as well as for the most publishing Canadian cities and Canadian organizations, by domain, field and subfield of science,

[22] This reclassification explains the drop from 6 domains to 5 domains, 22 fields to 22 fields, and 176 subfields to 174 subfields, as the classification in the 2016 report covered one general domain, two general fields and two general subfields. These do not exist anymore as their content is now reclassified at the paper level.

[23] http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf

[24] For methodology, see https://www.elsevier.com/products/scival/overview/topics#2-methodology

and over time, starting in 2012 and up until 2023 (2012–2017, 2018–2023 and 2012–2023 aggregated; 2012–2023 by year). These data were only produced where applicable, considering the appropriate lower thresholds whereby data would become unreliable or uninformative; generally, Science-Metrix does not compute any statistics below a sample size of 30 papers.[25] It is important to note that the amount of data generated was too great for presentation within the analytical report and presentation to the Expert Panel. As such, these data were provided to CCA in the form of an Excel database, which can be accessed by the client any time a specific need for data is encountered. Science-Metrix recognizes the importance of being reflective and not just descriptive when it comes to providing useful information for decision-making. In this respect, Science-Metrix's analysts synthesize, interpret and draw conclusions from the available information and aim at only communicating the most relevant findings to the Expert Panel through this analytical report and presentation.

### 5.3.1 Output-related indicators

#### Number of publications (full and fractional counting)

This indicator presents the number of publications for a given entity (e.g., country, province, scientific field), using either a full counting or fractional counting method. Using the full counting method, each publication is counted once for each entity it represents. For example, if a paper published in a health science journal is authored by two researchers from Health Canada, one from the University of Ottawa, and one from Columbia University, this publication will be counted once for Health Canada, once for the University of Ottawa, once for Columbia University, once for Canada, once for the United States and once in the health science field.

The second method, known as fractional counting, divides publications based on the proportion of authors who contributed to a paper. For example, if a paper is authored by a total of four researchers, with two of these authors under addresses from Health Canada, one author from the University of Ottawa and one author from Columbia University, the publication is then divided into four equal "parts," with Health Canada receiving two of those parts (0.5 publications), the University of Ottawa receiving one part (0.25 publications) and Columbia University receiving the remaining part (0.25 publications). Furthermore, Canada would receive 0.75 publications and the United States 0.25 publications from this article. In cases where a single author is assigned to more than one address, the fraction belonging to this author is further divided over the number of addresses. For instance, if one author should receive 0.5 publications, but is assigned to two addresses, each of these addresses receives 0.25 publications so that the sum across all combinations of authors and addresses still remains 1. Ideally, each author on a paper should be attributed a fraction of the paper that corresponds to his or her level of participation in the experiment compared to the other authors. Unfortunately, no reliable means exists for calculating the relative effort of authors on a paper, and thus each author is granted the same fraction of the paper. Some journals now include information about the contribution of authors to papers, which could be used to

[25] Number of publications does not equal sample size here, as some publications do not have paper-level values for some indicators. For instance, normalized citation scores are not computed for recent publications, therefore entities might have more than 30 papers, but less than 30 with the needed value. This is why some entities have more than 30 papers but non-computed metrics.

weight the papers differently based on author contributions, but since not all journals adhere to this practice, this information is not used for this report.

For this report, the fractional counts of publications was selected as the main output indicator for the selection of most publishing countries and for reporting.

### Growth ratio

The growth ratio (GR) measures the rate at which production changed for a given entity between one period of time and another—in the case of the present report, between the periods 2012–2017 and 2018–2023. As such, it is computed as the ratio of output using fractional counting in 2012–2018 over that of 2019–2023. A growth ratio of 1 indicates no change in production, while a growth ratio above 1 indicates growing levels of output and scores below 1 indicates a decrease in production.[26] So, for example, an entity increasing its output level from 1,000 publications in 2012–2017 to 1,200 in 2018–2023 would have a GR of 1.20 (20% increase). Because the GR is a single number that does not communicate information on the yearly fluctuations within a trend, output trend data for each entity is also included as a bar graph in the results tables. The growth ratio is measured using fractional counts of publications.

### Growth index

The growth index (GI) of an entity is the GR of that entity relative to the GR of a reference entity (e.g., the world, a country) in the same domain, field or subfield of science:

$$GI = \frac{GR_X}{GR_N}$$

where $GR_X$ is the growth ratio of entity X and $GR_N$ is the growth ratio of reference entity N. In the context of this study, two GIs are presented: one with the world acting as reference entity ($GI_{World}$), and another with Canada as reference entity ($GI_{Canada}$). These two indicators allow for an easier interpretation of the changing levels of outputs of countries and provinces, putting these into perspective with the reference growth trends.

### Specialization Index

The specialization index (SI) is an indicator of research intensity in a given entity (e.g., a country) for a given research area (e.g., a field), relative to the intensity in a reference entity (e.g., the world, or the entire output as measured by the database) for the same research area. In other words, when a country is specialized in a field, it places more emphasis on that field at the expense of other research areas. Specialization is therefore said to be a zero-sum game: the more one specializes somewhere, the less it does elsewhere. To ensure that it is a real zero-sum game, the publication numbers used to compute the SI are based on fractional counting. The SI is formulated as follows:

[26] In the case of Canadian provinces, because assignation of Canadian addresses to provinces is mostly based on city information and postal codes, and because of an increase in missing information relative to cities in the Scopus database for 2014, growth ratios for provinces are slightly overestimated. However, based on tests reassigning unknown addresses to Canadian provinces based on the share of each province, this underestimation is mostly negligible, with scores being shifted upwards by marginal amounts for most provinces when a correction is applied.

$$SI = \frac{S_X/T_X}{S_N/T_N}$$

Where:

$S_X$: Number of patents from entity X in a given technological field (e.g., number of patents owned by Canadian assignees in chemical engineering);

$T_X$: Total number of patents from entity X (e.g., total number of patents owned by Canadian assignees);

$S_N$: Number of patents from reference entity N in a given technological field (e.g., number of worldwide patents in in chemical engineering);

$T_N$: Total number of patents from reference entity N (e.g., total number of worldwide patents).

An index value above 1 means that a given entity is specialized relative to the reference entity, whereas an index value below 1 means the reverse.

Fractional counting is used so that a single paper is not counted several times. This approach avoids the use of total numbers across entities (e.g., researcher, institution, region, country) that add up to more than the total numbers of papers, as is the case with full-counting.

### 5.3.2 Impact-rated indicators

#### Average of relative citations

This is an indicator of the scientific impact of papers produced by a given entity (e.g., the world, a country, an institution) relative to the world average (i.e., the expected number of citations). The number of citations received by each publication is counted for the year in which it was published and for all subsequent years. For papers published in 2000, for example, citations received in the 2000–2024 period are counted. To account for different citation patterns across fields and subfields of science (e.g., there are more citations in biomedical research than in mathematics) and for differences in the age of publications (e.g., older papers have accumulated citations over a longer period), each publication's citation count is divided by the average citation count of all publications that were published the same year in the same subfield to obtain a relative citation count (RC). A minimum three-year citation window (i.e., publication year + two years) is required for the computation of the RC, which results in the RCs only being computed up until year 2021. The ARC of a given entity is the average of the RCs of the papers belonging to it. An ARC value above 1 means that a given entity is cited more frequently than the world average, while a value below 1 means the reverse. Note that Science-Metrix does not compute the ARC for entities with fewer than 30 publications with an RC score. Because RC scores cannot be computed for unclassified publications, this may lead to the absence of ARC scores for entities with slightly more than 30 publications.

#### Average of field-weighed CiteScore (FWCS)

For this report, the FWCS replaced the MRIF, which was based on the Impact Factor, another journal-level metric. The average of field-weighted is a measure of the "quality" of an entity's papers, based on

the CiteScore[27] of the journals in which they were published. The CiteScore of publications is calculated by attributing to them the CiteScore of the journal in which they are published, for the year in which they are published. Subsequently, to account for different publication patterns across fields and subfields of science (e.g., medicine journals usually have a higher IF than mathematics journals), each publication's CitesCORE is divided by the average CiteScore of all papers that were published the same year in the same subfield to obtain a relative CiteScore (RCS). The CiteScore of a journal is computed over four years, using the number of citations received by a journal in that year and the previous three years, for the documents published in the journal in the total four year-period. This number is then divided by the count of documents indexed in the journal during the same four-year period. For example, in 2017, the CiteScore of a journal would be equal to the number of citations of articles published in 2017 (8), 2016 (15), 2015 (9), and 2014 (13) divided by the number of articles published in the journal in 2017 (15), 2016 (23), 2015 (12), and 2003 (10) and 2002 (16) (i.e., IF = numerator [45] / denominator [60] = 0.75). This indicator can be computed up until the last publication year available in the database.

Caution is advised when analyzing averaged scores for entities based on journal metrics, as these are proxies for the propensity of countries, provinces, cities and organization in publishing in high impact journals, but does not speak about the actual citations made to the entities themselves, nor to the actual quality of the research performed. At high levels of aggregation, the ARC and FWSC tend to correlate strongly, but at lower aggregation levels, it is possible for entities to publish in low impact journals and present with high normalized citations scores, and on the opposite entities can publish in high impact journals, but garner low levels of citations.

### Papers in the 10% most cited publications ($HCP_{10\%}$)

This represents the share of output from an entity falling into the top 10% most cited publications at the world level based on relative citations scores (RC), which are normalized by the average within a subfield of science and year of publication as previously described in the description of the ARC. It is important to note that this indicator is computed by taking the number of publications of an entity being in the top 10% most cited, and dividing this number by the number of publications of an entity with a valid RC score (i.e., total number of publications excluding the more recent publications for which RC scores could not yet be computed and unclassified publications). Then, this score is divided by 10% to obtain a normalized score centred at 1.00. When the $HCP_{10\%}$ score is above 1, it means that an entity has more publications in the top 10% most cited than expected; when it is below 1, it means the opposite. Note that Science-Metrix does not compute the $HCP_{10\%}$ score for entities with fewer than 30 publications with a RC score.

Because some publications are tied based on their RC score, including all publications in the database that have an RC score equal to or greater than the 10% threshold often leads to the inclusion of slightly more than 10% of the database. To ensure that the proportion of publications in the 10% most cited publications in the database is exactly equal to 10% of the database, publications tied at the threshold RC score are each given a fraction of the number of remaining places within the top 10%. For example, if a database contains 100 publications (i.e., the top 10% should contain 10 publications) and the 9th, 10th,

[27] https://www.elsevier.com/products/scopus/metrics/citescore

11th and 12th publications all have the same score according to the RC, they are each given a quarter of the remaining two places in the top 10% (a score of 0.5 within the 10% most cited). In addition, in some cases, the number of places in the 10% most cited publications is not an integer (e.g., if there are 11 publications in the database, there should be 1.1 publications in the top 10%). In this case, there is a dual fractionation of ties at the threshold. In the above example, the paper with the highest score is given a count of 1, and the second paper is given a count of 0.1 if there is no tie in the RC score of papers at the threshold. If three papers are tied in second place behind the first paper, they are each given a weight of 0.03 (i.e., 0.1 × 1/3). If the top 2 papers are tied, they are each given a count of 0.55 (i.e., 1.1 / 2) and so on.

Note that scores for the 1% most cited publications, while not presented in this report, are available in the Excel database accompanying this report.

### Citation Distribution Index (CDI) and Citation Distribution Chart (CDC)

By applying the fractioning method described above for the indicator on papers in the 10% most cited publications to all the publications, it is possible to sort all publications across 10 citation deciles—that is, to determine to which citation deciles publications belong. In most cases, publications fully belong to only one decile (i.e., a score of 1 for a decile and 0 for all the other nine), but in many cases, because of ties at borders of deciles, publications will be ranked in two different deciles, the sum across deciles always adding up to 1 for a given publication. This allows for the computation of scores similar to those prepared for the 10% most cited, centred at 1 when the number of publications within a decile is equal to expectation, but this time for each of the 10 citation deciles.

If an entity performed just as well as the world generally, it would be expected to have exactly 10% of its publications in each of the 10 deciles. In reality of course, an entity will diverge from this expected pattern as its citation impact increases or decreases relative to the world generally. As shown in Figure 4, this type of chart shows 10 colour-coded bars; each bar representing one decile. The bar's colour shows whether the entity has more or fewer publications in that decile than expected (green denotes production exceeding expectation in that decile, red denotes production below expectation in that decile), and the length of the bar shows how far above/below expectation the entity is in that decile. Where a decile has no bar associated with it, this shows that the entity's performance is exactly in line with the expectation based on global performance (i.e., a score of 1). Accordingly, a chart with no visible bars at all shows that the entity in question has 10% of its papers in the 1st global decile, 10% of its papers in the 2nd global decile, and so on.

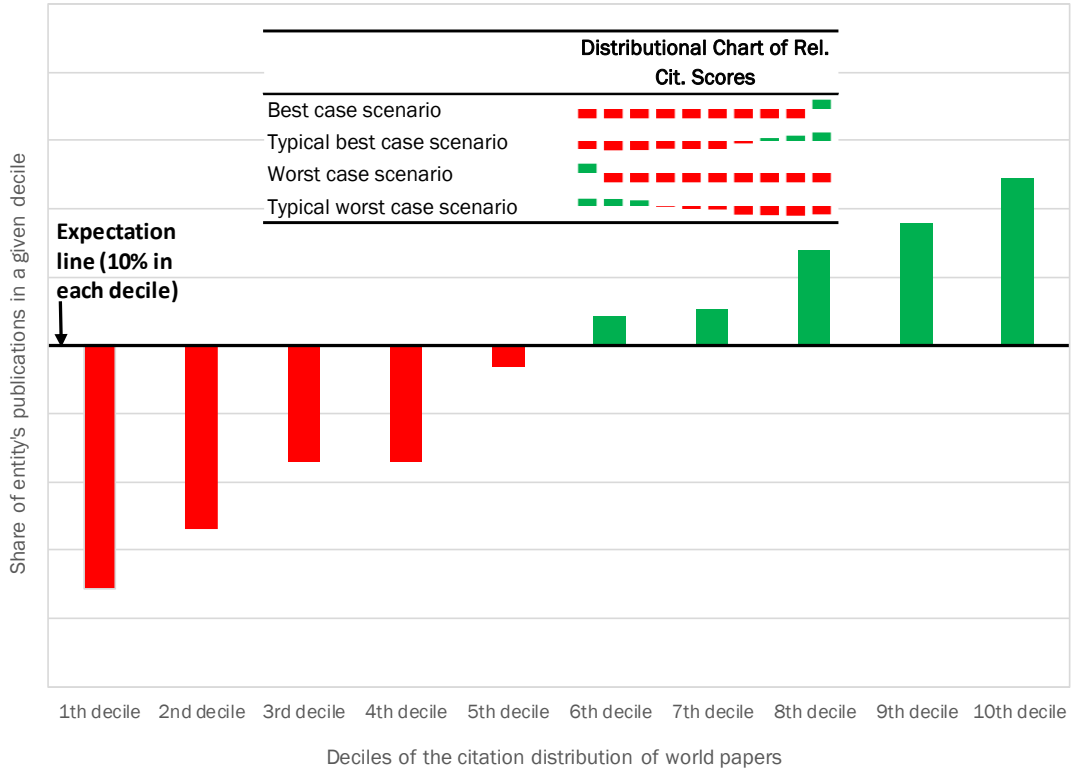


Figure 4 Citation Distribution Chart (CDC)
Source: Prepared by Science-Metrix

Ideally, one would hope to be overrepresented in the highest deciles, where the most impactful publications are found; similarly, one would hope to be under-represented in the lowest deciles, where the least impactful publications are found. Thus, strong research performance is shown by long red bars on the left of the chart and long green bars on the right. Contrarily, weaker research performance is depicted with long green bars on the left side (indicating more publications than expected in the less impactful deciles) and long red bars on the right side (indicating fewer publications than expected in the more impactful deciles). These charts can be presented within condensed dashboards as in the small table within Figure 4. The resulting indicator, which applies a weighting of each decile, from -5 for the lowest decile to +5 for the highest one, is called the Citation Distribution Index (CDI), and varies from -50 (worst performance, all output in lowest decile) to +50 (best possible performance, all output in highest decile), with 0 acting as the world reference.

### 5.3.3 Cross-disciplinarity-related indicators

Interdisciplinary research combines knowledge or methods from two or more academic disciplines into one activity (e.g., a research project). Interdisciplinary research is becoming increasingly important as many of the most pressing problems facing society today require solutions that draw on knowledge from

multiple disciplines.[28] To measure interdisciplinarity and multidisciplinarity, we use as proxies the disciplinary diversity of authors (DDA) and disciplinary diversity of references (DDR).

Here are examples of public reports and publications for these indicators:

- 2022: Do women undertake interdisciplinary research more than men, and do self-citations bias observed differences? | Quantitative Science Studies (MIT.edu)
- 2021: Evaluation of the Belmont Forum (belmontforum.org)

### Disciplinary diversity of authors (DDA)

The DDA reflects the diversity of the prior disciplinary backgrounds of a paper's co-authors. This indicator was developed to account for the number of distinct disciplines, the cognitive distance that separates them, and the balance between them. A paper co-authored by authors whose previous papers were distributed across subfields of science in a similar pattern (i.e., having similar relative frequency across subfields) would score lower than papers bringing together authors with different backgrounds (as measured by the subfields from their prior publications), even if those authors, individually, have published in a less diverse set of subfields. In other words, it is having differences between the backgrounds of each co-author that increases multi-disciplinary integration and not having individual authors with more diverse backgrounds. Nevertheless, authors having diverse backgrounds may be more likely to increase the multi-disciplinary integration of one paper, but only if this diversity is sufficiently different from the subfields of the remaining authors. As a result of this approach, a single-author publication, no matter the diversity of its author's background, will always receive the minimum score, because the indicator is intended to capture diversity across different authors. Similar to the DDR, the share of an entity's papers with a DDA score in the top 10% will be measured and normalised to the average of all papers worldwide published in the same subfield and same year.

Share of highly multidisciplinary publications refers to the share of an entity's papers among the top 10% with the highest DDA in the world. The share in the top 10% is used in the report instead of the average DDA score because the distribution of DDA score is quite narrow. Higher scores based on the most multidisciplinary papers tend to be easy to connect with actual multidisciplinarity.

### Disciplinary diversity of references (DDR)

The DDR of a publication is computed based on the material cited by the publication and reflects the diversity of knowledge that is being integrated into the publication. The indicator considers (a) the number of different subfields that are being cited, (b) the distribution of those citations across the cited subfields, and (c) the intellectual proximity of those subfields to one another. For example, a paper that draws on knowledge from four different subfields would have a higher DDR score than a paper that draws on only three. Similarly, a paper that cites one subfield 90% of the time and the other subfields only 10% of the time would have a lower score than a paper that cites its various subfields in roughly equal measure. Finally, a paper that integrates knowledge from biology and from chemistry would have a lower score than a paper that integrates knowledge from biology and the performing arts, because the former pair is

[28] https://www.inscits.org/disciplinary-diversity---theory-and-praxis

more intellectually proximate than the latter pair. In this report, the share of an entity's papers among the top 10% with the highest DDR in the world will also be computed. As for the HCP, each paper's DDR score is adjusted to the average of all papers worldwide published in the same subfield and same year.

Share of highly interdisciplinary publications refers to the share of an entity's papers among the top 10% with the highest DDR in the world. The share in the top 10% is used in the report instead of the average DDR score because the distribution of DDR score is quite narrow. Higher scores based on the most interdisciplinary papers tend to be easy to connect with actual interdisciplinarity.

### 5.3.4 Collaboration-related indicators

#### Number of co-publications

A co-publication is defined as a publication that was co-authored by different authors. By counting the number of co-publications from a country with co-authors from at least one other country, the number of international co-publications for this country is obtained. By counting the number of co-publications from a province with co-authors from at least one other provinces, the number of inter-provincial co-publications for this province is obtained. The number of Canada's international co-publications and those of other leading countries were computed, as well the number of inter-provincial co-publications of Canadian provinces. The number of public–private co-publications was also measured, where a public entity is defined as any non-/not-for-profit entity. Most of the public sector publications in Canada belong to the academic sector, with some contributions from governmental institutions.

The number of co-publications of an entity can be expressed in absolute terms or as a percentage of the entity's total scientific output. Full counting is used in these cases. As described above, when applied to publications with authors from different countries, the number of international co-publications is obtained. When this number is divided by the total number of publications, the international collaboration rate (ICR) is obtained. However, because the status of some publications cannot be assessed properly because of addresses with unknown countries (e.g., a publication with two addresses, one from Canada and another one from an unknown country, cannot be definitely declared as an international co-publication or not), these publications are excluded in the denominator. This is why the ICR is often slightly higher than scores obtained by dividing the number of international co-publications by the number of papers provided in the Excel database.

At the world level, the ICR is the weighted average of scores from all countries. At the Canadian level, the interprovincial collaboration rate is the weighted average of scores from all provinces and territories. The weighted average approach is implemented to account for the fact that some publications count toward the score of collaboration rates of multiple countries/provinces, which, in extreme collaboration scenarios, can lead to almost all entities performing above the world/Canadian level.[29]

[29] China is a good example of this, as the vast majority of its publications are single country. Given China's large output at the world level, this results in a relatively low share of papers involving two countries at the world level (around 25%), while most countries have an ICR well above 40%.

### Probabilistic Affinity Index (PAI)

The Probabilistic Affinity Index evaluates the number of observed co-publication ties between pairs of countries against their expected number of ties. This expected number is calculated by randomly redistributing all pairwise co-publications within the collaboration network, taking into account each country's size. The index values range from 0 (indicating fewer collaborations than expected or negative affinities) to 1 (as expected), and can exceed 1 for pairs with more collaborations than anticipated (positive affinities). In this report, we only include country pairs with an expected occurrence of at least 30, as scores for less frequent pairs are susceptible to yearly fluctuations and noise.

$$PAI_{xy} = \frac{C_{xy}}{T \times \left(\left(\frac{C_x}{T} \times \frac{C_y}{T - C_x}\right) + \left(\frac{C_y}{T} \times \frac{C_x}{(T - C_y)}\right)\right)}$$

Where,

$C_{xy}$ = Observed number of co-publications between countries x and y

$C_x$ = Total number of co-publications of country x with all other countries

$C_y$ = Total number of co-publications of country y with all other countries

$T$ = Total number of pairwise co-publications of all countries (reciprocal pairs (e.g., CA−US and US−CA counted only once in calculating T)

### Asymmetrical Probabilistic Affinity Index ($PAI_{Asym}$)

Many collaboration indicators, including the Probabilistic Affinity Index (PAI), treat all co-publications between two countries as equal partnerships. However, researchers from a given country may play a more central role in driving the research, leading to inherent asymmetries in co-authors' contributions. The Asymmetrical Probabilistic Affinity Index ($PAI_{Asym}$) addresses this asymmetry by assessing how the inclination to collaborate varies depending on whether a country is in a leading or participating role.

In the $PAI_{Asym}$ framework, the corresponding author is designated as the leader of the publication. This assumption is based on the understanding that the corresponding author is often the principal investigator (PI) and may also be the first or last author, thereby playing a crucial role in determining the composition of the research team, coordinating the project, and potentially providing significant financial support. All other authors are assigned a participatory role.

The $PAI_{Asym}$ for country x (as leader) in relation to country y (as participant) is calculated as the ratio of co-publications where country x is the leader and country y is a participant, divided by the expected number of co-publications between country x and country y (where x leads and y participates). The expected number is determined by randomly redistributing the total co-publications where country x leads, while accounting for the size of country y as a participant (i.e., its total co-publications with any leading country x).

$$PAI_{ASYMx \neq y} = \frac{C_{xL \rightarrow yP}}{C_{xL} \times \frac{C_{yP}}{T_P - C_{xP}}}$$

Where,

$\mathbf{C_{(xL \rightarrow yP)}}$ = Observed co-publications between $\mathbf{C_x}$ and **Cy, where $\mathbf{C_x}$ is leading and $\mathbf{C_y}$ is participating**

$\mathbf{C_{xL}}$ = Total co-publications of $\mathbf{C_x}$ with all other countries, when $\mathbf{C_x}$ **is leading**

$\mathbf{C_{xP}}$ = Total co-publications of $\mathbf{C_x}$ with all other countries, when $\mathbf{C_x}$ **is participating**

$\mathbf{C_{yP}}$ = Total co-publications of $\mathbf{C_y}$ with all other countries, when $\mathbf{C_y}$ **is participating**

$\mathbf{T_P}$= Total number of pairwise co-publications of **all countries when participating**

Index values range from 0 (indicating fewer collaborations than expected or a negative affinity of country x to collaborate with country y) to 1 (as expected), and can exceed 1, indicating that country x collaborates with country y more frequently than anticipated (positive affinity of country x for country y).

### 5.3.5 Multi-criteria analysis: Composite indicator of scientific performance

Multi-criteria analysis is a synthesis tool used in bibliometrics to inform the decision-making process in the science policy context. When several dimensions characterizing the scientific performance of an entity (e.g., a country) are being measured for comparative purposes, it is often difficult to determine the position of entities being compared relative to one another without a well-structured ranking mechanism. Various methods have been developed in the scientific literature to reduce numerous indicators to a single composite indicator or multi-rank. However, these methods are often sensitive to the composition of the study sample: the position of two entities relative to one another (i.e., A performs better than B or vice-versa) can be altered if entities are added or removed from the sample. A similarity-based approach to ranking multi-criteria alternatives was adapted to provide a stable composite indicator and multi-rank in a bibliometric context. The method ranks alternatives based on their degree of similarity to the positive-ideal solution. The key aspect of this approach consists of setting the positive-ideal solution to constant values regardless of the composition of the sample by determining, theoretically or empirically, the maximum and minimum possible values of each indicator. The similarities are computed by projecting each alternative's vector of N dimensions (i.e., N indicators) on the reference vector (i.e., the ideal solution vector) using the cosine of the angle between them. The resulting indicator varies between 0 (worst possible performance) and 1 (best performance possible). The method allows the weight of individual indicators to be adjusted so as to reflect the relative importance attributed to these measures by decision-makers. This tool was developed with the aim of synthesizing information pertaining to the performance of an entity and to ease the decision-making process.

In this study, Science-Metrix used its composite indicator to identify scientific areas of strength for Canada, its provinces, its cities and organizations. For this report, this tool was used at different geographic levels, to compare Canada to other leading countries, provinces against one another, cities against one another, and organizations against one another. In that case, the ranked alternatives are the entities from the same geographic level (e.g., composite performance of Canada versus Australia in physics, Alberta versus British Columbia in biology, Waterloo against Toronto in clinical medicine). These

analyses were performed at the domain, field and subfield levels. The indicators included in this analysis are as follows:

- number of papers (frac) (20%);
- growth ratio (GR) (10%);
- specialization index (SI) (15%);
- average of relative citations (ARC) (20%);
- highly cited publications ($HCP_{10\%}$) (15%).
- difference in diversity of authorship top 10% ($DDA_{10\%}$) (10%);
- difference in diversity of references top 10% ($DDA_{1R\%}$) (10%)

The composition of the composite indicator sometimes depends on the level at which it is calculated. For example, when computed for the total scientific production of an entity, the SI results in a contribution of 0.15 points for all entities since its value is 1 for all entities, and thus shifting slightly the effective weight of each remaining indicator up as the differencing is now happening on the 0.85 remaining points.

Because the composite is computed independently within each geographical level, it is critical to remember that composite scores are not comparable across disciplines. Readers should thus never compare scores across disciplines, and should instead refer to ranks when attempting to compare across disciplines.

### 5.3.6 Emerging research areas

To identify areas of growing research activity in Canada and its provinces, the growth ratios (GR) at the Canadian and world levels were calculated (See Section 5.3.1). The GR values for Canada were compared to the GR calculated for the world in order to ascertain whether the increase experienced by the entity has kept pace with the world increase in this research area.

## 5.4 Technometric indicators

Analyzing innovation from patent databases such as PatentsView and PATSTAT is less straightforward than analyzing publication data, since PATSTAT indexes information on patent applications from multiple patenting offices around the world. Because there is no international patent office, inventors must file a patent application in every jurisdiction where they wish to seek protection for their invention. Therefore, no patent office provides comprehensive information on patented inventions on the global scale. Considering this limitation, for the purpose of this study, patents granted by the United States Patent and Trademark Office (USPTO) and the European Patent Office (EPO) are analyzed. Since the United States is the largest market globally, the most innovative creations tend to be patented there. Consequently, the USPTO is one the largest registries of patented inventions in the world. PatentsView provides information on the patents' inventors, their location and citations in the U.S. market. PATSTAT provides similar information across more than 100 offices, but data quality for most of these is not high enough to prepare robust metrics, which is why only results from the EPO are prepared from this source for this report. During the application process, inventors assign technological fields to their inventions. Fields are not mutually exclusive; a patent can therefore be classified in multiple fields, unlike publications. The following sections list each technometric indicator presented in this report.

### 5.4.1 Output-related indicators

#### Number of granted patents

As with publications, the number of patents (or owned intellectual properties (IPs) is presented in both full and fractional counting using a fractioning method similar to that used for scientific publications. Each patent lists a group of assignees (individuals and/or legal entities who own the patent) and a group of inventors (who are strictly individuals but have no ownership rights to the patent). The number of granted patents and all other technometric indicators are strictly calculated based on the location of the assignees unless specified otherwise. Data are presented for both the USPTO and EPO separately.

One important difference with scientific publications is that unlike the subfields assigned to publications, technological fields in PATSTAT are not mutually exclusive. Each patent is fractionally distributed among all fields assigned to it. As such, because of these multiple assignations, the sum across technological fields will more than often add up to a higher number of IPs than the presented total using full counting. However, these sums will equal the computed totals using fractional counting. For example, a patent assigned to the fields of inorganic chemistry and chemical engineering will count for half in both fields using fractional counting, but will be counted once per field using full counting.

#### Growth ratio

The growth ratio is computed in the same manner as the GR for scientific output, but using numbers of patents instead of numbers of scientific publications. (see Section 5.3.1).

#### Growth index

The growth index is computed in the same manner as the GI for scientific output, but using fractional numbers of patents instead of numbers scientific publications. (see Section 5.3.1).

#### Flow of intellectual property

The flow of intellectual property (IP) of an entity is the relative difference between the number of patents granted according to their assignees belonging to that particular entity and the number of such patents according to their inventors belonging to the same entity. For example, the flow of IP in Canada would be calculated as follows:

$$\frac{\binom{Number\ of\ patented\ inventions}{owned\ by\ Canadian\ assignees} - \binom{Number\ of\ patented\ inventions}{created\ by\ Canadian\ inventors}}{Number\ of\ patented\ inventions\ created\ by\ Canadian\ inventors}$$

Fractional counting is used for this indicator. Note that in order to avoid biasing results if some countries or provinces are overrepresented on addresses that could not be assigned because of missing information, patents with unknown addresses were reassigned to countries/provinces according to their respective share of the total output that could be assigned. A negative flow represents a deficit in terms of innovation and ownership of IP, while a positive flow is indicative of the reverse.

#### Specialization index

This is an indicator of the concentration of patents of a given geographic or organizational entity in a given technical field or sector relative to a reference entity in the same field/sector. For example, if the

percentage of Canadian patents (the geographic entity) in the field of biotechnology is greater than the percentage of patents in this field at the world level (the reference), then Canada is said to be specializing in this field. This is computed in the same manner as the SI for scientific output, relying on fractional counts of patents (see Section 5.3.1).

### 5.4.2 Impact-related indicators

#### Average of relative citations (ARC)

Like publications, patents give and receive citations. However, unlike the subfields assigned to publications, technological fields in PatentsView and PATSTAT are not mutually exclusive. In order to account for disparities in citation practices between different technological fields, each patent is fractionally distributed among all fields assigned to it. For example, a patent assigned to the fields of inorganic chemistry and chemical engineering will count for half in both fields. A RC score is calculated based on this fractioning for each field, and ultimately used to calculate the ARC as the harmonic mean across the fields on the patent. The ARC is normalized to 1, meaning that an ARC score above 1 indicates that the entity's patents have greater-than-normal impact; an ARC score below 1 indicates that the entity's patents have less-than-normal impact. Given that the ARC is computed using RC scores and that RC scores are normalized to the world level, the ARC is reflective of an entity's technological impact relative to the world level.

### 5.4.3 Multi-criteria analysis: Composite indicator of technological performance

In this study, Science-Metrix used its composite indicator to identify technological areas of strength for Canada and its provinces (similar to composite indicator for scientific performance, see Section 5.3.5). This tool was also used to compare Canada to other leading countries. These analyses were performed at the technical sector and technical field level. The indicators included in this analysis are as follows:

- number of granted patents (frac) (20%);
- growth ratio (GR) (20%);
- specialization index (SI) (20%);
- average of relative citations (ARC) (20%); and
- flow of IPs (20%).

The composition of the composite indicator sometimes depends on the level at which it is calculated. For example, when computed for the total technological production of an entity, the SI is excluded since its value is 1 for all entities. Weights then become:

- number of granted patents (frac) (30%);
- growth ratio (GR) (30%);
- average of relative citations (ARC) (20%); and
- flow of IPs (20%).

For organizations, since the flow of IPs is not computed, weights then become:

- number of granted patents (frac) (30% with SI, 40% without);
- specialization (SI); (30% with SI, 0% without);

- growth ratio (GR) (20% with SI, 30% without); and
- average of relative citations (ARC) (20% with SI, 30% without)

## 5.5 Positional analysis

To visualize the composite performance of countries and provinces, positional analysis graphs were also produced. To more easily interpret the strengths and weaknesses of a country or province through the use of several separate indicators, Science-Metrix uses these graphical representations (see example below). This graphical representation logically combines three of the previously mentioned indicators (number of papers (frac), SI and ARC).

The horizontal axis of this positional graph corresponds to the SI and the vertical axis to the ARC. These data are transformed to obtain a symmetrical distribution of possible values between −100 and +100, with zero representing the world level. The size of the bubbles is proportional to the number of papers produced by the country or province.

The position of a country or province in one of four quadrants can therefore be interpreted as follows:

- **Quadrant 1:** Located at the top right of the graph, this quadrant is synonymous with excellence. Entities in this quadrant specialize in the given domain and their activities have a high impact, meaning that their papers are more frequently cited than the world average in this domain.
- **Quadrant 2:** Located at the top left of the graph, this quadrant is synonymous with high impact scientific production, but the entities are not specialized in the domain.
- **Quadrant 3:** Located at the bottom right of the graph, this quadrant signals specialization in the domain, whereas output impact is below the world median.
- **Quadrant 4:** Located at the bottom left of the graph, this quadrant represents the worst case scenario, as both the intensity of activity and its impact are below the world level in the domain.