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Canada

Patenting to Fight Pandemics

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ABOUT US

The Canadian Intellectual Property Office (CIPO), a Special Operating Agency of Innovation, Science and Economic Development Canada (ISED), is responsible for the administration and processing of Intellectual Property (IP) in Canada. CIPO contributes to Canada's innovation and economic success by providing greater certainty in the marketplace through high-quality and timely IP rights, fostering and supporting invention and creativity through knowledge sharing, raising awareness to encourage innovators to better exploit IP, helping institutions compete globally through international cooperation and the promotion of Canada's IP interests, and administering Canada's IP system and office efficiently and effectively.[1]

EXECUTIVE SUMMARY

The Government of Canada has taken a number of measures to respond to the issues brought on by COVID-19. One such response is the *Pandemic Response Challenge Program*, initiated by the National Research Council of Canada (NRC), with its goal to fast-track breakthroughs to support the fight against COVID-19. As patent data is often a useful starting point for analyzing the development of new technologies, the Canadian Intellectual Property Office (CIPO) has collaborated with the NRC to present the patent landscape for pandemic mitigation technologies.

The purpose of this report is to highlight Canadian patented inventions between 1999 and 2018, with a particular focus on three research areas that align with NRC's *Pandemic Response Challenge Program*, namely, Therapeutics and Vaccine Development, Rapid Detection and Diagnosis, and Digital Health. The patent search strategy identified more than 11,000 patented inventions globally during this 20 year time period, of which approximately 2% of the patented inventions by institutions worldwide were attributed to Canadian institutions. Patented inventions in this area worldwide have grown annually by 17% on average, from 45 in 1999 to 874 in 2018.

Institutions based in the United States of America and China held the largest patent portfolios for pandemic mitigation technologies and together accounted for more than 50% of the total patented inventions considered for this analysis. Patented inventions by Chinese institutions grew significantly over the last decade and have recorded a higher than average annual growth rate. Canadian institutions ranked eighth globally for pandemic mitigation technologies in terms of number of patented inventions. With an annual growth rate of 8% between 2009 and 2018, Canadian institutions' growth is on par with institutions originating from leading economies such as Germany and Japan. Canadian institutions filed predominantly at CIPO (46%), followed by Intellectual Property India (13%) and the United States Patent and Trademark Office (11%).

Furthermore, Canadian institutions were found to have a relatively high specialization in pandemic mitigation technologies. This expertise is spread out amongst numerous Canadian institutions, as more than 60% of these Canadian inventions were held by institutions that held less than five patented inventions. Within Canada, most of the innovation occurred within the Montreal and Vancouver Census Metropolitan Areas (CMA) followed closely by the Toronto CMA.

Upon further examination of the three research areas defined by the NRC's *Pandemic Response Challenge Program*, more than 50% of the pandemic mitigation patented inventions were related to Therapeutics and Vaccine Development. In addition, the bulk of the patent activity for this research area was evident in 2004 in institutions worldwide, in contrast to 2008 in Canadian institutions.

Although this report does not present patent activity resulting from the recent pandemic, as this data is not available yet, it provides a useful overview of the patenting behaviour during and following past outbreaks. The information presented in this report can be used to understand the state of innovation as it relates to technologies that could support in finding solutions to assist in protecting the population from this extremely contagious and deadly virus.

INTRODUCTION

Severe acute respiratory syndrome coronavirus 2, commonly known as COVID-19, belongs to a family of viruses known as the Coronaviruses which cause respiratory illnesses.[2] There are two strains belonging to this group of viruses that have caused major outbreaks in the past: severe acute respiratory syndrome (SARS), and the Middle East respiratory syndrome (MERS).[3] As COVID-19 affects many nations on varying scales, governments across the globe are moving at an unprecedented scale in order to mitigate the most serious threats resulting from the COVID-19 pandemic.

The Government of Canada has also been working with partners across the public and private sector to develop solutions to address the challenges presented by COVID-19. One such effort has been led by Canada's largest federal research and development (R&D) organization, the National Research Council of Canada (NRC).[4] Through the creation of Challenge programs, the NRC is partnering with the private and the public sector, academic and other research organizations in Canada and internationally to advance transformative, high-risk, high-reward research that address Canadian priorities.[5]

Of particular interest for this report is NRC's *Pandemic Response Challenge Program*, wherein the NRC received $15 million to form dedicated teams to address challenges in the areas of greatest R&D need in the fight against COVID-19. This Program brings together Canadian and international researchers to accelerate R&D aimed at specific COVID-19 gaps and challenges identified by Canada's health experts. Teams are built from government, universities, and Canadian business to accelerate the development of diagnostics tools and medical countermeasures for a rapid front-line response. This Challenge program is structured around the following three research areas:[6]

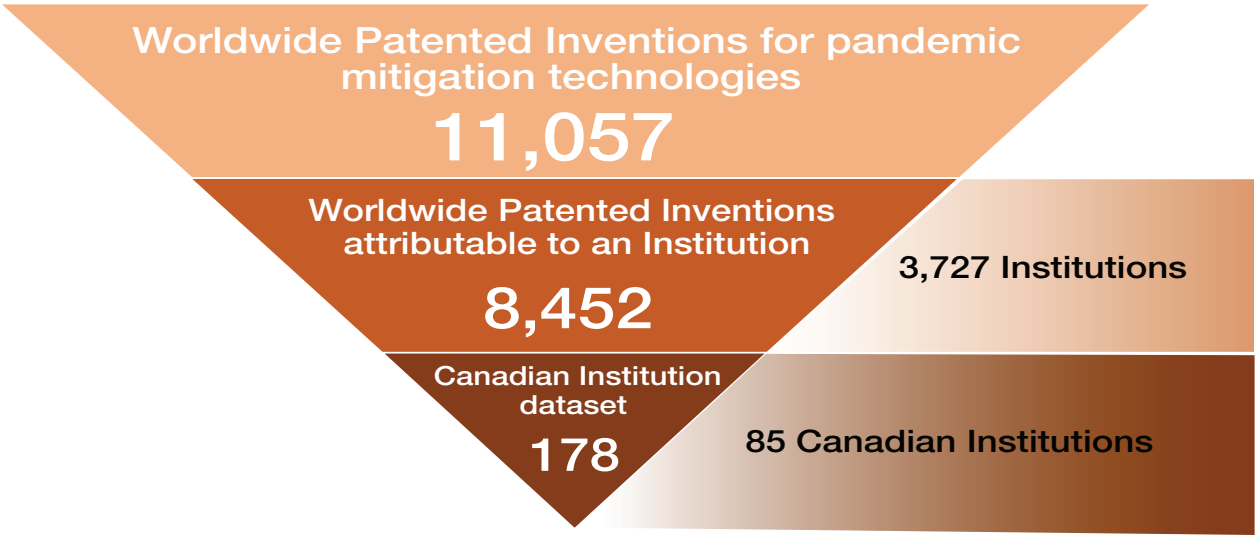
1. *Therapeutics and Vaccine Development*, which involves developing biologics and antibodies to counteract a disease in the critically ill.
2. *Rapid Detection and Diagnosis*, which involves detecting and diagnosing the COVID-19 virus with advanced methodologies and sampling technologies based on molecular signatures.
3. *Digital Health*, which leverages technology to assist in the delivery of healthcare. This includes developing low-cost, high-precision contactless sensor systems for widespread patient monitoring and personalized artificial-intelligence assistants to help remote and vulnerable populations, among other applications.

Not only will this report highlight Canadian innovation undertaken during prior outbreaks, both domestically and abroad, but will also identify institutions that have patented inventions related to pandemic mitigation technologies. The patent search strategy for this report has been developed in collaboration with our colleagues at NRC who have prior patent examination experience. This report presents the global patent landscape for this field, with an emphasis on the leading Canadian institutions, their area of expertise and their collaborations, as well as the regional clusters throughout the country where patent activity is concentrated.

DATASET

Using the patent search strategy developed in collaboration with the NRC to examine the research areas related to its *Pandemic Response Challenge Program*, more than 11,000 patented inventions[i] were identified globally for pandemic mitigation technologies between the application years 1999 and 2018. Of these, approximately 8,500 patented inventions were found to be assigned to institutions, which for the purpose of this report encompasses academic institutions, businesses, government departments, medical facilities and research organizations. 178, or 2.1% of the patented inventions by institutions worldwide included at least one Canadian institution as an assignee[ii]. Annex A of this report provides additional details regarding the patent search strategy.

Figure 1: Breakdown of the dataset analyzed for this report ranging from application year 1999 to 2018



[i] The term "patented inventions" in this report pertains to priority filings of INPADOC patent families.

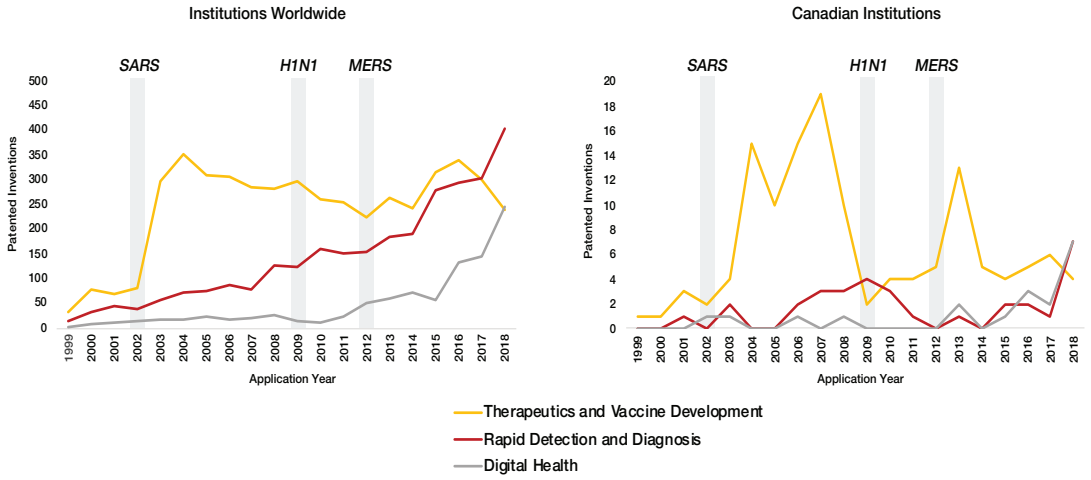
[ii] The term "assignee" includes institutions as well as inventors who were assigned the rights to an invention.

In order to gain a deeper understanding of the technologies that encompass this field, the dataset has been further broken down according to the three research areas identified in the NRC's *Pandemic Response Challenge Program*. As seen in Figure 2, more than half of the patented inventions by institutions worldwide fall under the Therapeutics and Vaccine Development research area. In particular, a greater proportion of the Canadian patent activity is concentrated in Therapeutics and Vaccine Development when compared to all institutions worldwide.

Figure 2: Distribution of patented inventions across the three research areas for institutions worldwide (*left*) and Canadian institutions (*right*)

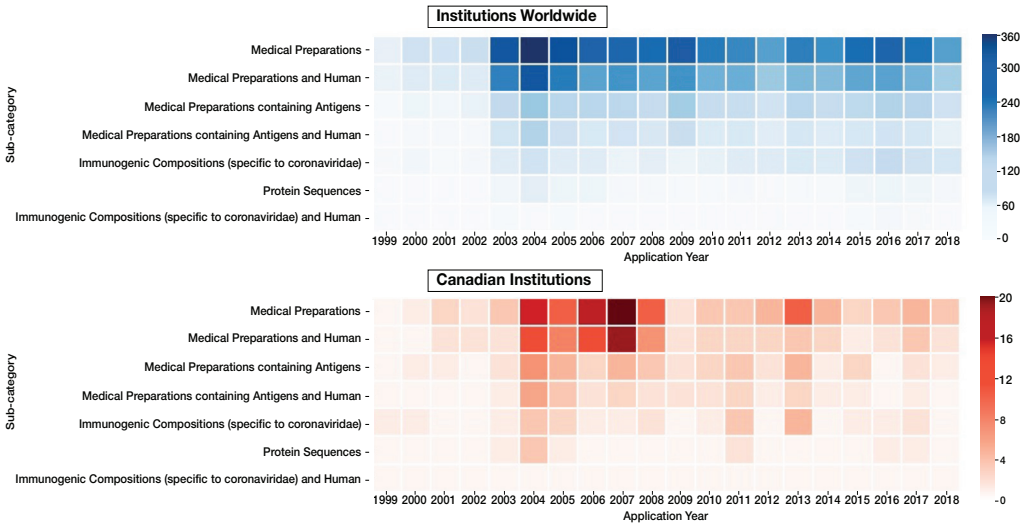
The growth of patented inventions by institutions worldwide and Canadian institutions across the three research areas between the application years 1999 and 2018 is shown in Figure 3. The three grey bars in each graph indicate the onset of the SARS, H1N1 and MERS outbreaks. This figure suggests that patented inventions by institutions worldwide grew steadily for Rapid Detection and Diagnosis over this time period, whereas patented inventions for Digital Health remained relatively low until the MERS outbreak. Interestingly, patented inventions by institutions worldwide surged for Therapeutic and Vaccine Development after the SARS outbreak and then remained relatively stable. It is also worth noting the spikes in patented inventions by Canadian institutions for Therapeutics and Vaccine Development that followed the SARS and MERS outbreaks.

Figure 3: Growth of patented inventions across the three research areas for institutions worldwide (*left*) and Canadian institutions (*right*)



The heat maps presented in Figure 4 provide insight into the sub-categories examined for the Therapeutics and Vaccine Development research area and depict the patenting intensity within each of these sub-categories over time. The maps also show that the bulk of the patent activity for this research area was evident in 2004 in institutions worldwide, in contrast to 2007 in Canadian institutions.[iii]

Figure 4: Growth of patented inventions for Therapeutics and Vaccine Development by institutions worldwide (*top*) and Canadian institutions (*bottom*)



[iii] Due to low patent intensity for Rapid Detection and Diagnosis, as well as Digital Health, the heat maps showcasing the growth of their respective sub-categories over time have been excluded from this report.
For a list of sub-categories examined for these two research areas, refer to the patent search strategy in Annex A.

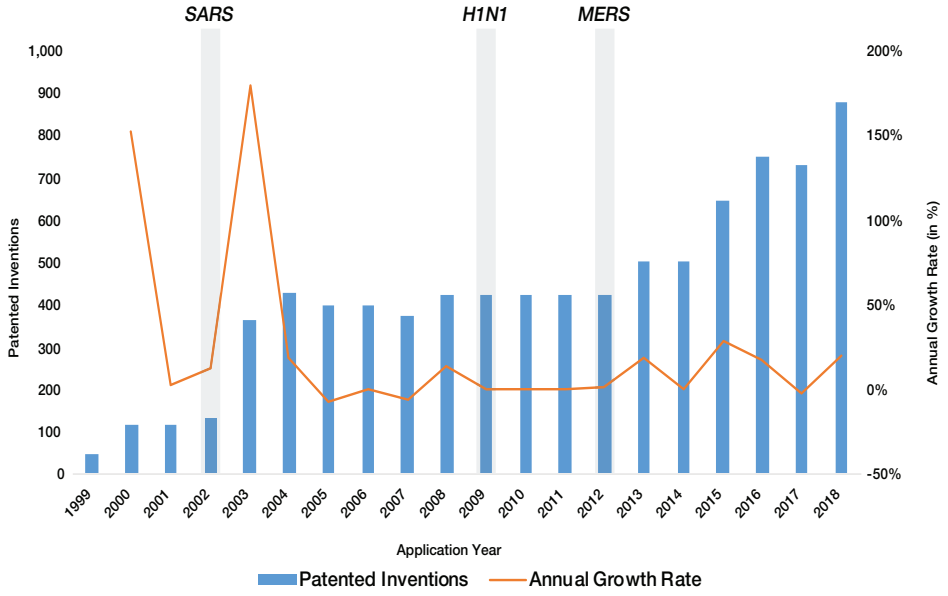
INTERNATIONAL IMPORTANCE OF IP FOR PANDEMIC MITIGATION TECHNOLOGIES

This section presents the innovation that has been carried out by institutions worldwide for pandemic mitigation technologies. Using patent activity as a proxy for measuring innovation, this section explores the patent landscape for this field between 1999 and 2018.

Global Trend for Patented Inventions

Figure 5 shows the global trend for patented inventions for pandemic mitigation technologies between application years 1999 and 2018. During these two decades, the average annual growth rate of patented inventions was 17%. At the turn of the century, there was a limited number of patented inventions in this field; however, a significant spike in patent activity is observed between 2002 and 2004 following the SARS outbreak. After 2004, the growth for patented inventions remained relatively stable until the onset of the MERS outbreak, after which an annual average growth of 13% is observed between 2012 and 2018.

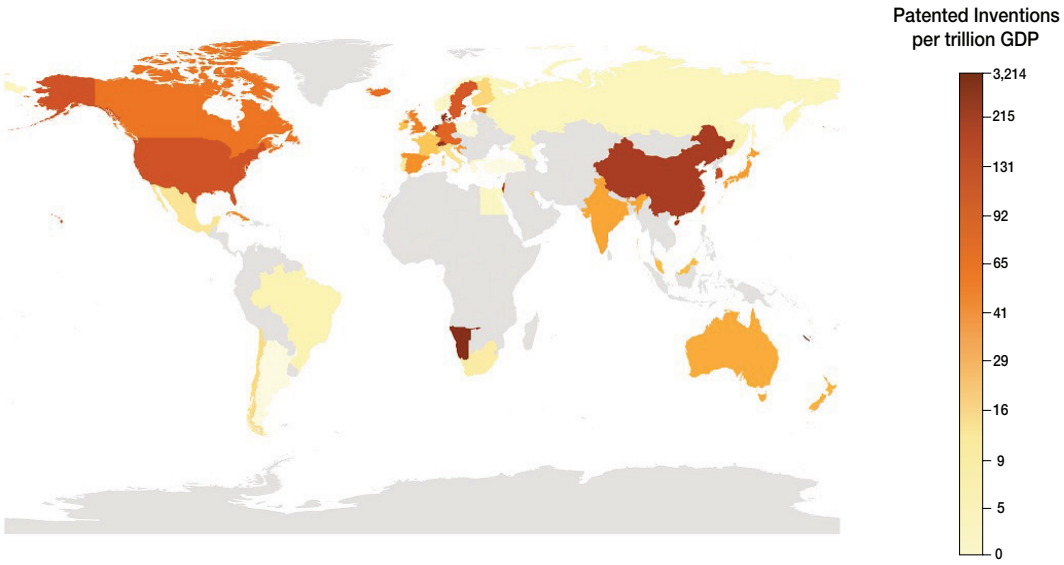
Figure 5: Global growth of patented inventions for pandemic mitigation technologies between 1999 and 2018



Geographical Clusters of Patent Activity

The Figure 6 displays the patenting intensity of each country's institutions for pandemic mitigation technologies. The patented invention volume for each country has been normalized by the country's Gross Domestic Product (GDP) value for 2018 to adjust for the size of the economy.[iv,7] After accounting for this, smaller economies like Liechtenstein, Namibia and Denmark emerge as leaders in this field. However, in terms of absolute fractional counts, institutions from the United States of America (USA) and China are clear leaders, since they were cumulatively responsible for more than 50% of the total patented inventions considered for this analysis. Canadian institutions hold the eighth largest patent portfolio in this field.

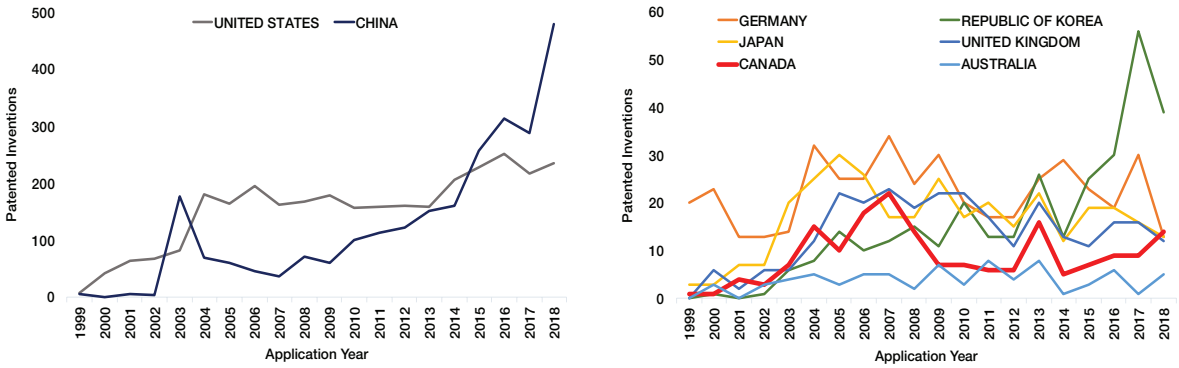
Figure 6: Global patent activity by institution's country of origin for pandemic mitigation technologies



[iv] A fractional counting approach was used to compute the patented invention counts for each country. This approach avoids double counting for patented inventions that involve multiple assignees from different countries. For example, in the case where an invention is patented by an American inventor and two Canadian inventors, Canada would be assigned two-thirds of the patented invention count and the U.S. would be assigned the remaining third.

Figure 7 showcases the growth in patented inventions for select countries in this field. Chinese institutions have made considerable headway between 2009 and 2018 and have recorded an average annual growth rate of 26%, which is significantly higher than the 8% average annual growth rate observed by institutions worldwide during this same period.[v] In line with the worldwide average annual growth rate, Canadian institutions also experienced an average annual growth rate of 8% over the second half of the 20-year timeframe and it is encouraging to see this growth being almost on par with institutions from leading economies like Germany and Japan.

Figure 7: Global patent filing trend for pandemic mitigation technologies by institution's country of origin between 1999 and 2018



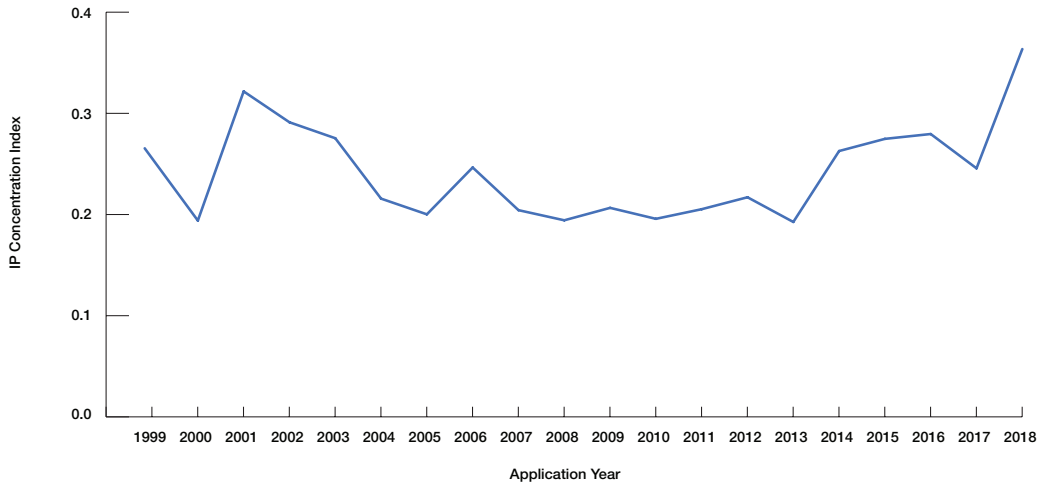
[v] China's representation in the global patent dataset is incomplete for the timeframe considered in this analysis. This is due to the China National Intellectual Property Administration (CNIPA) not publishing the applicant information for patented inventions at their office. As a result, China will not be used to benchmark Canada's performance in this report. Inventions originating from Chinese applicants that are patented abroad are assumed to be accurately captured by the respective filing offices that administer the international filings. The following dashboard illustrates this fact: https://public.tableau.com/profile/patstat.support#!/vizhome/CoverageofPATSTAT2019SpringEdition/CoveragePATSTATGlobal

IP Concentration among Countries

In order to gauge the degree of concentration of patented inventions globally, CIPO has developed a metric called the Intellectual Property Concentration Index (IPCI). This index can be used to determine the competitiveness of an industry or technology field based on the distribution of patented inventions held by all the countries active in that industry or field (additional details in Annex C). Index values closer to 0 indicate a more competitive global environment with no single country dominating, whereas index values closer to 1 would indicate a more concentrated global environment with one country clearly dominating.

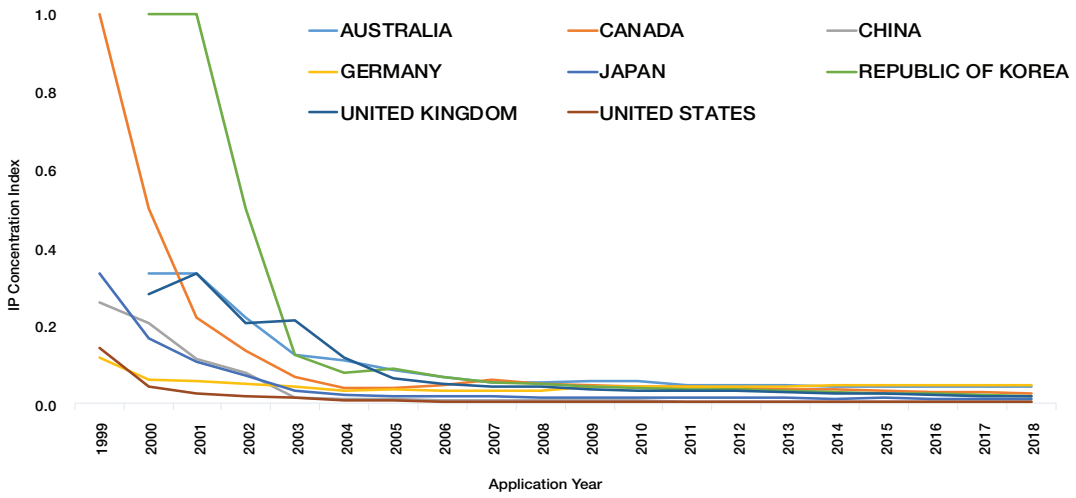
Figure 8 shows the change in IPCI value over time for pandemic mitigation technologies for all institutions worldwide. After observing a peak value of 0.32 in 2001, the IPCI gradually stabilizes to a value of around 0.2 between application years 2004 and 2013. After 2013, one can notice an upward trend in the IPCI value over time which eventually attains its peak value of 0.36 in 2018. This uptick in IPCI value indicates an increase in patent activity from institutions originating from a few select countries. Based on the trend observed in Figure 7, this uptick in IPCI value is a result of the surge in patented inventions by Chinese institutions. The remaining countries, including Canada, form a competitive fringe to this dominant position.

Figure 8: Intellectual Property Concentration Index for pandemic mitigation technologies between 1999 and 2018



In contrast to presenting the aggregated shift in concentration of patented inventions across all countries as in Figure 8, the IPCI in Figure 9 captures the degree of competitiveness for institutions originating from each respective country for pandemic mitigation technologies. When a new technology typically emerges into the marketplace, there are relatively few institutions engaged in this new field. As a result, these institutions operate in a less competitive environment and their country's IPCI value is therefore expected to be high; that is, closer to 1. As this technology matures over time and becomes recognized globally, the market becomes a more competitive environment as new institutions enter, resulting in the IPCI declining over time. The trends observed in Figure 9 align with these expectations as the IPCI for all countries, including Canada, is observed to be below 0.1.

Figure 9: Intellectual Property Concentration Index for institutions from select countries for pandemic mitigation technologies between 1999 and 2018



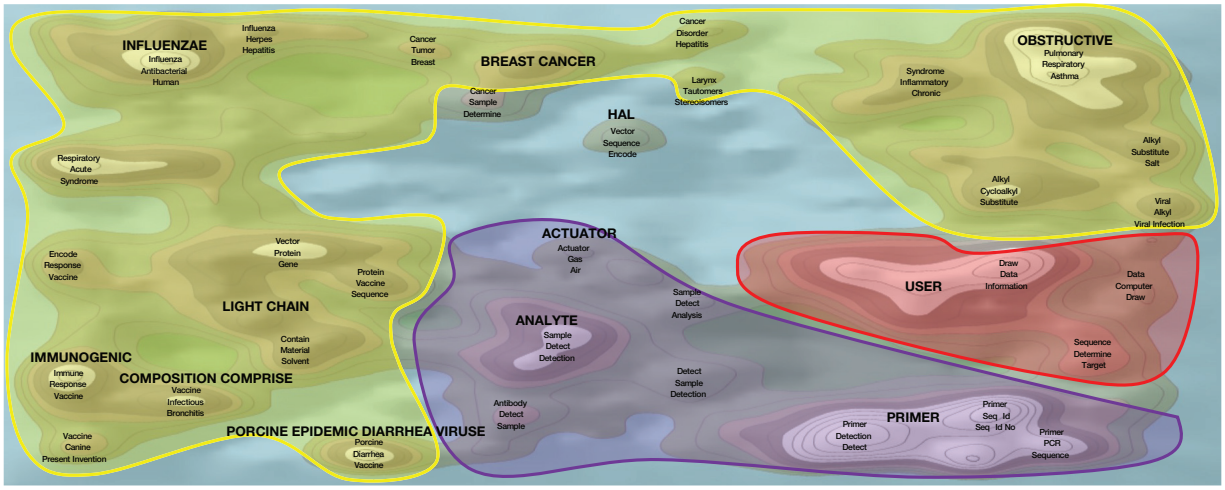
Global Patent Landscape

The patent landscape map presented in Figure 10 is helpful in identifying the key areas that experienced high patent activity for pandemic mitigation technologies. This map is generated using an algorithm that relies on word sequences from patent documentation to cluster patented inventions according to shared language. The patented inventions are organized based on common themes and grouped as "contours" on the map to identify areas of high and low patent activity. The white peaks represent the highest concentrations

of patented inventions, and each peak is labelled with key terms that tie the common themes together. The contours are further highlighted to represent the research areas they fall under. The distance between word sequences helps to illustrate the relationship between peaks, where shorter distances indicate that the patented inventions they represent share more commonalities relative to those that are further apart. Word sequences located close together may be part of similar systems or technologies, whereas word sequences that are further apart are less likely to be related or share less in common.

Figure 10 highlights the overlap between pandemic mitigation technologies and other foundational technologies that were initiated between 1999 and 2018. Coronavirus induces many symptoms similar to that of other viral respiratory infections, such as influenza and many of the interventions were originally intended for other infections. This explains why inventions that relate to research on the pathophysiological mechanisms of influenza infections, and of other bacteria, are of great value as pandemic mitigation. Similarly, it is expected that gastrointestinal and pulmonary inflammatory conditions appear in Figure 10, as coronavirus is known to cause both respiratory and gastrointestinal symptoms.[8] Indeed, mechanisms of immune response to these conditions and to cancer are also implicated in the immune response to coronavirus, which explains the overlap with the patented inventions related to light chain of antibody immunoglobulins. Similarly, for the Rapid Detection and Diagnosis research area, the patented inventions related to primers, polymerase chain reactions and antibodies are valuable foundational technologies for the pandemic.

Figure 10: International patent landscape map for pandemic mitigation technologies



ANALYSIS FROM A CANADIAN PERSPECTIVE

This section provides a snapshot of the innovative efforts undertaken by Canadian institutions on a global scale for pandemic mitigation technologies between the application years 1999 and 2018. The 178 patented inventions considered to present this snapshot were assigned to at least one Canadian institution. Not only does this section showcase the growth in patenting inventions, but it highlights Canadian geographical clusters having a high patenting intensity and benchmarks Canadian institutions against their international counterparts.

Canadian Trend for Patented Inventions

Figure 11 shows the global trend for patented inventions by Canadian institutions between application years 1999 and 2018 where patented inventions grew annually by 15% on average. This growth is almost on par with the growth experienced by institutions worldwide during this timeframe. The figure also shows an increase in patent activity after the onset of the SARS outbreak in 2002. This upward trend continued until 2007 during which patent activity by Canadian institutions grew annually by 49% in comparison to the 23% experienced by institutions worldwide. The second uptick in patented inventions observed follows the MERS outbreak in 2012.

Figure 11: Patent activity by Canadian institutions for pandemic mitigation technologies between 1999 and 2018[vi]

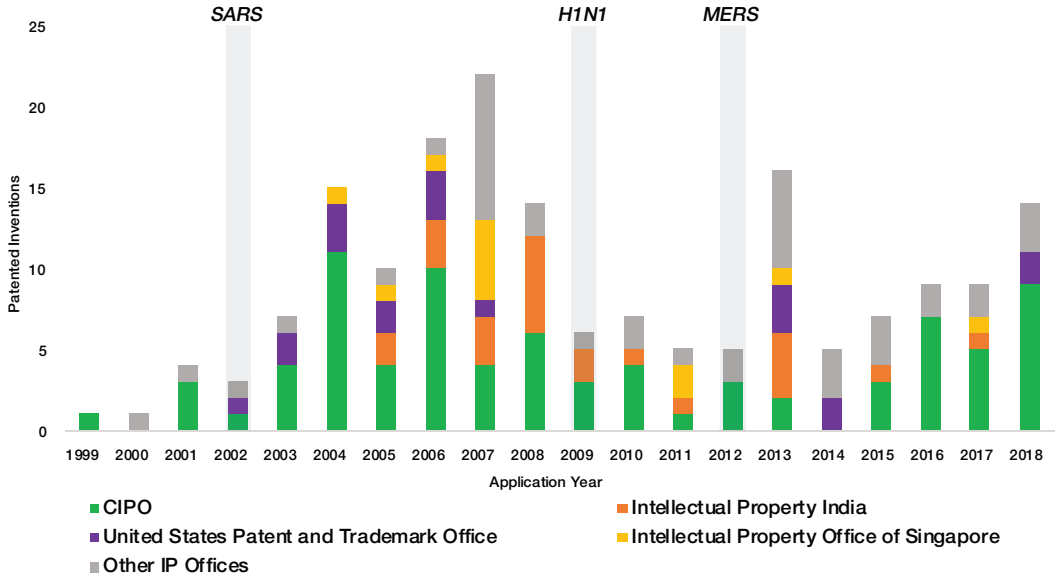


Figure 11 also identifies intellectual property offices targeted by Canadian institutions to patent inventions pertaining to pandemic mitigation technologies. Canadian institutions have been filing predominantly at CIPO (46%), Intellectual Property India (13%), United States Patent and Trademark Office (11%) and Intellectual Property Office of Singapore (7%) for this field. Interestingly, almost 39% of these inventions have been administered by the World Intellectual Property Organisation's through the Patent Cooperation Treaty (PCT), which could speak to the global importance of these inventions.

While Canada and the U.S. are prominent filing jurisdictions for Canadian institutions across most technology areas, the presence of India and Singapore may be explained by the specialisation these countries have held in pandemic mitigation technologies. India is a global manufacturing hub for pharmaceuticals, and may therefore be an attractive filing destination for Canadian institutions.[9] Similarly, Singapore is a regional hub for both pharmaceutical manufacturing and R&D, and may therefore also be a sought-after destination for Canadian institutions patenting in pandemic mitigation technologies.[10]

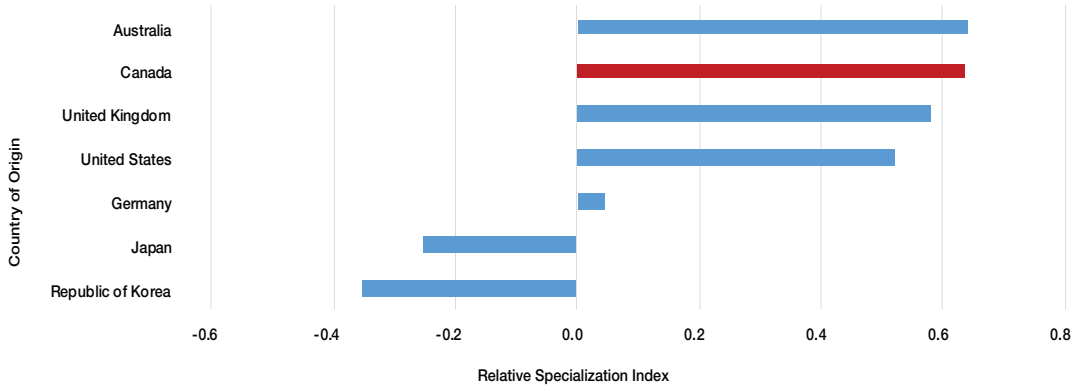
[vi] Other IP offices in Figure 11 include:

- Brazilian Patent and Trademark Office
- China National Intellectual Property Administration
- Directorate General of Intellectual Property (Indonesia)
- European Patent Office
- Intellectual Property Office of Vietnam
- IP Australia
- Korean Intellectual Property Office
- Mexican Institute of Industrial Property
- Netherlands Patent Office

Relative Specialization of Canadian Institutions

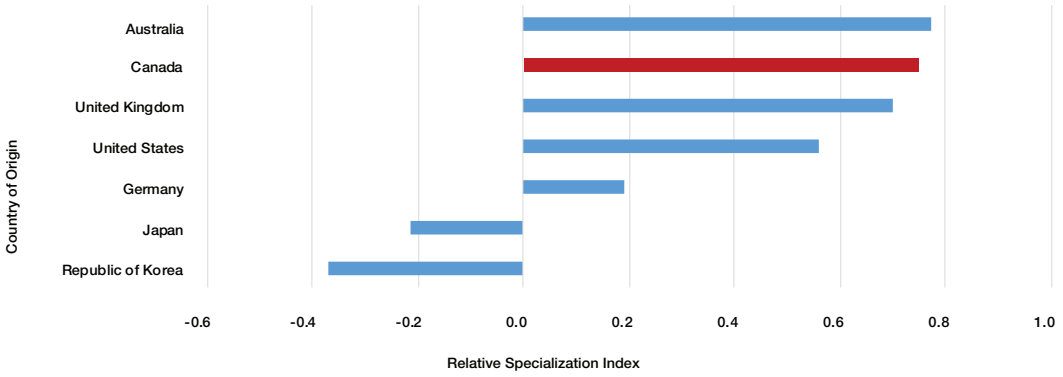
After gaining a better understanding of the jurisdictions targeted by Canadian institutions for pandemic mitigation technologies, the following figure examines the degree of specialization Canadian institutions hold in this field when compared to institutions from other countries using the Relative Specialization Index (RSI). This index uses patenting intensity to allow for institutions originating from countries of different sizes to be compared for a particular technology field on a relative basis (additional details in Annex D). If a country's institutions have an RSI value of greater than 0 for a particular technology field, they are considered to be more specialized in that particular field when compared to all institutions worldwide and vice-versa. Furthermore, a country's institutions having an RSI value of 0 would be considered just as specialized as all institutions combined for a particular technology field. In Figure 12, Canadian institutions have one of the highest RSI values thereby indicating a relatively high specialization for pandemic mitigation technologies.

Figure 12: Relative Specialization Index by institution's country of origin for pandemic mitigation technologies



In reference to Figure 13, it is interesting to note that institutions originating from countries considered in Figure 12, including Canadian institutions, retain their level of relative specialization for the Therapeutics and Vaccine Development research area.

Figure 13: Relative Specialization Index by institution's country of origin for Therapeutics and Vaccine Development



Having established the high relative specialization of Canadian institutions for the Therapeutics and Vaccine Development research area in Figure 13, Table 1 presents the evolution of Canadian institutions for this research area and benchmarks it against institutions from other countries. Upon breaking down the dataset over the two decades that were considered for this analysis, it is clear that, except for Medical Preparations and Human, the relative specialization of Canadian institutions has improved over time for all the sub-categories presented in the table.[vii]

Table 1: Relative Specialization Indices by institution's country of origin for Therapeutics and Vaccine Development

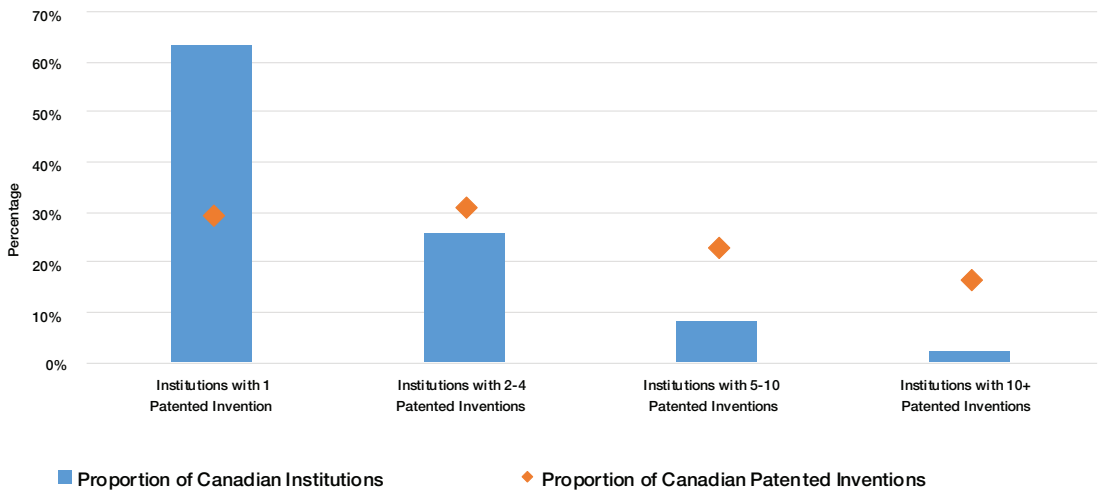
Institution's Country of Origin	Relative Specialization Index											
	Medical Preparations			Medical Preparations and Human			Medical Preparations Containing Antigens			Immunogenic Compositions (specific to coronaviridae)		
	1999-2008	2009-2018		1999-2008	2009-2018		1999-2008	2009-2018		1999-2008	2009-2018	
Australia	0.00	0.05	↑	-0.06	-0.10	↓	0.43	0.39	↓	0.10	0.34	↑
Canada	0.05	0.14	↑	0.05	-0.01	↓	0.08	0.24	↑	0.00	0.10	↑
United Kingdom	0.16	0.15	↓	0.01	0.14	↑	-0.24	0.12	↑	-0.20	-0.43	↓
United States	-0.02	0.09	↑	-0.10	0.10	↑	0.09	0.19	↑	-0.01	-0.27	↓
Germany	0.08	0.23	↑	0.17	0.35	↑	-0.48	0.03	↑	-1.31	-0.33	↑
Japan	-0.07	0.00	↑	-0.04	0.03	↑	0.02	0.15	↑	-0.18	-0.14	↑
Republic of Korea	0.00	0.07	↑	-0.10	-0.05	↑	-0.30	-0.17	↑	0.05	0.02	↓

[vii] Sub-categories for the Therapeutics and Vaccine Development research area that have not attracted considerable patent activity have been excluded from this table.

Patent Concentration among Canadian Institutions

After understanding where Canadian institutions' strengths lie in pandemic mitigation technologies, this section seeks to understand whether this specialization stems from a few select Canadian institutions, or if it is a result of a large number of Canadian institutions patenting in this field. In Figure 14, Canadian institutions have been grouped together on the basis of the number of patented inventions globally by each institution. The blue bars depict the proportion of Canadian institutions present in each group whereas the orange dots indicate the proportion of Canadian patented inventions associated with each group. Based on this figure, one can infer that Canadian institutions who have patented less than five inventions for pandemic mitigation technologies account for more than 60% of the Canadian patented invention dataset. This not only highlights the presence of a large number of Canadian institutions actively patenting in this field but could also speak to the competitive global environment they operate in.

Figure 14: Canadian institutions grouped by their pandemic mitigation technologies patent portfolio size

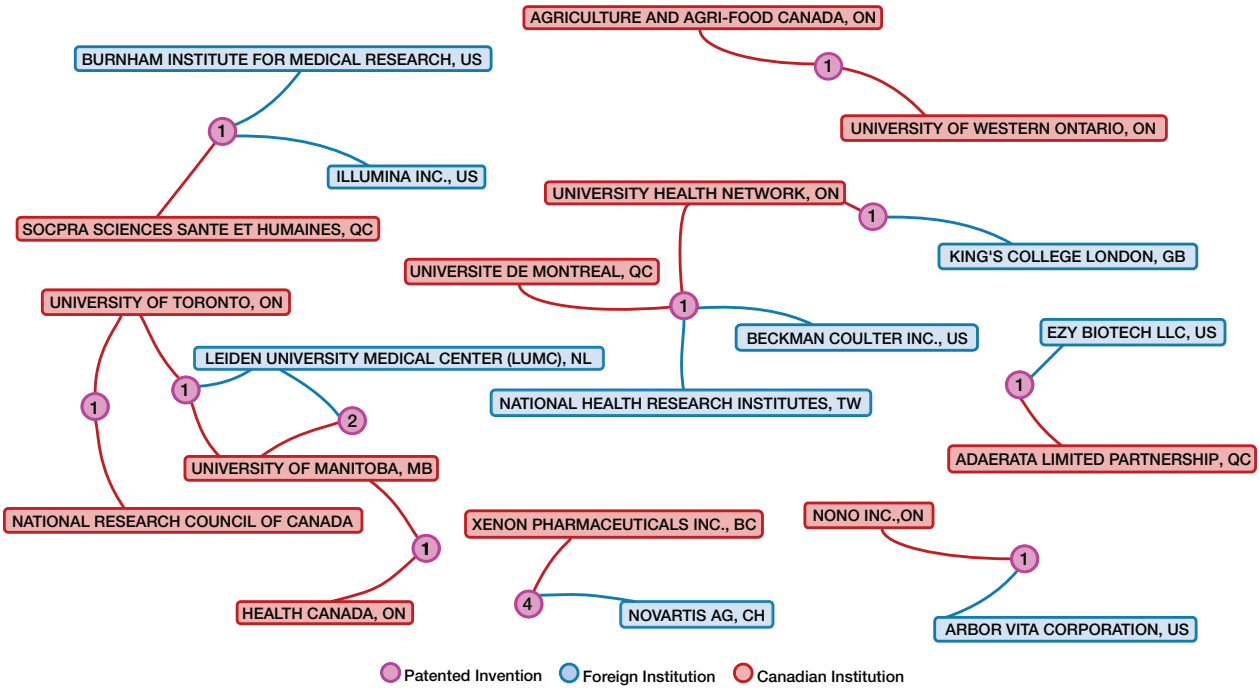


Collaboration among Institutions

Collaborations, involving domestic and international institutions, are often associated with technological advancements, especially during a crisis as overwhelming as a global pandemic. Interestingly, many businesses and academic institutions in Canada have taken the Open COVID Pledge, which is aimed at fostering collaboration and working towards the common goal of mitigating the impacts of the pandemic.[11] As part of this initiative, institutions will provide royalty-free, limited-time licenses to their IP, so that other institutions can develop and deploy technologies on a greater scale without any impediment.[12]

Figure 15 shows the collaborations involving at least one Canadian institution that have been identified using our dataset. The pink nodes in this figure indicate the number of patented inventions wherein two or more institutions were identified as joint assignees. In addition, Canadian institutions have been highlighted in red and international institutions have been highlighted in blue. Using this figure, it is encouraging to see different institution types (i.e., academic institutions, businesses, government departments and medical facilities) collaborating to develop solutions in this field. Interestingly, 7 out of the 15 patented inventions presented in this figure have at least one institution based out of the province of Ontario, followed by British Columbia (4 patented inventions), Manitoba (4 patented inventions) and Quebec (3 patented inventions). In addition, Canadian institutions have primarily collaborated with institutions from the U.S. (5 patented inventions), Switzerland (4 patented inventions) and the Netherlands (3 patented inventions) for pandemic mitigation technologies. It is also worth noting that all of the patented inventions involving a collaboration relate to Therapeutics and Vaccine Development except for the one collaboration between Adaerata and Ezy Biotech which is related to the Rapid Detection and Diagnosis research area.

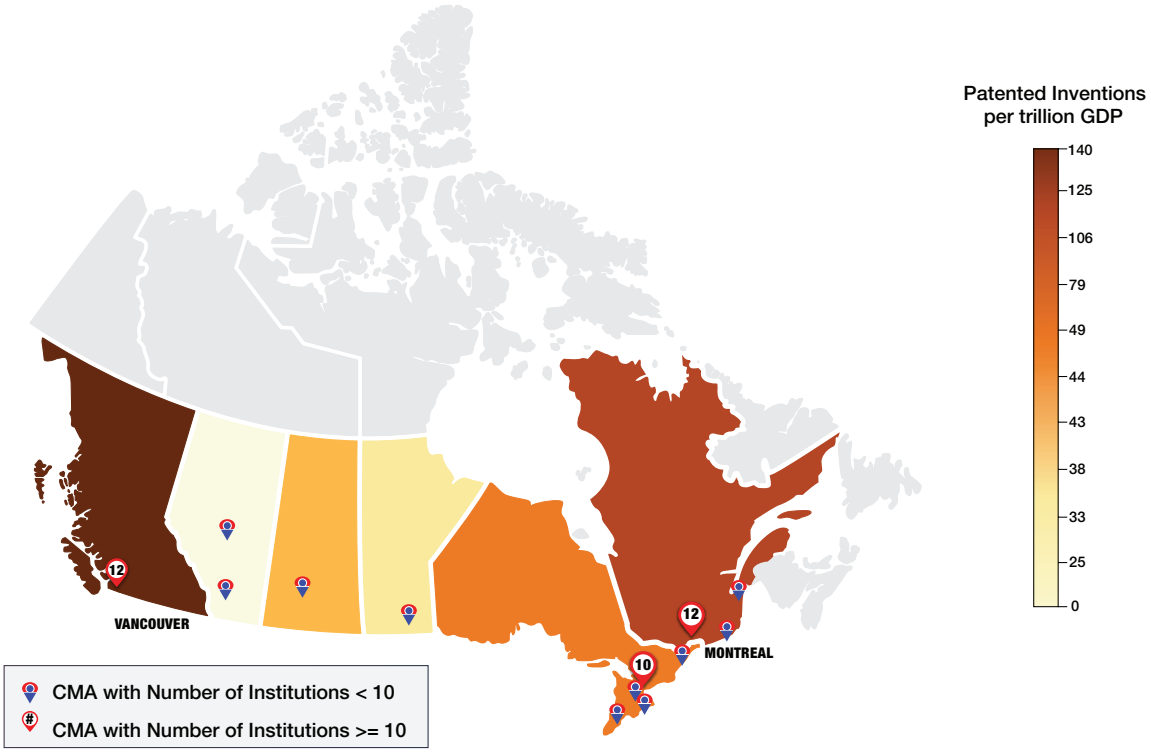
Figure 15: Collaboration among institutions for pandemic mitigation technologies



Regional Clusters of Patent Activity

Figure 16 shows the distribution of patent activity by Canadian institutions across provinces in Canada for pandemic mitigation technologies. The number of patented inventions for each province has been normalized by its GDP value for 2016, to better reflect the contribution of each province to innovation on a relative basis.[viii,13] The outcome from applying this normalization reveals that the province of British Columbia has the highest patenting intensity followed by Quebec and Ontario. The red location pointers in the figure highlight the innovation hotspots that exist within Canada for pandemic mitigation technologies and indicate the total number of institutions that have been identified within prominent Census Metropolitan Areas (CMA) using our dataset. Montreal and Vancouver CMAs, each with 12 institutions, have the highest number of institutions that have been patenting in this field followed closely by Toronto with 10 institutions. At least three-quarters of these institutions, across these 3 prominent CMAs, are businesses and the remaining quarter are academic institutions.

Figure 16: Regional clusters of patent activity by Canadian institutions for pandemic mitigation technologies



[viii] Fractional counting approach was used to compute the patented invention counts for each province.

Leading Canadian Institutions

The following set of tables include a list of leading Canadian institutions for each of the three research areas along with their top patenting inventors. Upon closer inspection of these tables, it is apparent that most Canadian institutions are associated with leading inventors having a Canadian registered address.

Table 2: Leading Canadian institutions and their top inventors for Therapeutics and Vaccine Development

Canadian Institution		Leading Inventors	
XENON PHARMACEUTICALS INC. (BC)	19	Kamboj Rajender	7
		Kodumuru Vishnumurthy (BC)	7
		Sun Shaoyi,Coquitlam (BC)	7
REPLICOR INC. (QC)	8	Vaillant Andrew (QC)	7
		Bazinet Michel (QC)	3
		Juteau Jean-Marc (QC)	3
MEDICAGO INC. (QC)	6	Vezina Louis-Philippe (QC)	3
		Couture Manon (QC)	3
		D'Aoust Marc-Andre (QC)	3
		Lavoie Pierre-Olivier (QC)	3
MERCK CANADA INC. (QC)	6	Black Cameron (QC)	4
		Crane Sheldon (QC)	4
		Robichaud Joel	2
UNIVERSITY HEALTH NETWORK (ON)	6	Kelvin David (ON)	3
		Persad Desmond (ON)	2
		Cameron Mark J. (ON)	2

Table 3: Leading Canadian institutions and their top inventors for Rapid Detection and Diagnosis

Canadian Institution		Leading Inventors	
FIO CORPORATION (ON)	9	Chan Warren Che Wor (ON)	5
		Greenberg Michael Mordinson (ON)	3
		Kain Kevin Charles (ON)	3
YES BIOTECHNOLOGY INC. (BC)	5	Whitehead Peter (BC)	5
LUMEN ASSOCIATES INC. (AB)	3	Fry Jeffrey Donald	2
		Gibson Hugh Stewart	2
		Kemp Douglas Roy	2
		Rosenstiel Leonie	2
EARLY WARNING INC. (QC)	2	Gordon Neil (QC)	2
		Palmateer Garry (ON)	2

Table 4: Leading Canadian institutions and their top inventors for Digital Health

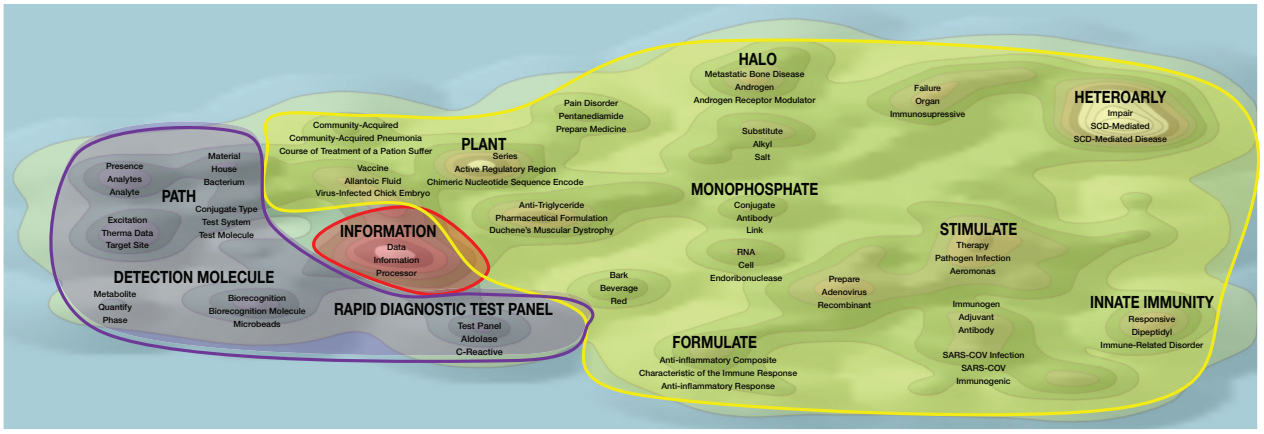
Canadian Institution		Leading Inventors	
YES BIOTECHNOLOGY INC. (BC)	4	Whitehead Peter (BC)	4
FIO CORPORATION (ON)	2	Fine Ian (ON)	2
		Liederman Adam (ON)	2
		Qandil Bayan (ON)	2

Canadian Patent Landscape

In Figure 17, the patent landscape map for Canadian institutions highlights the foundational technologies that were patented for pandemic mitigation technologies between 1999 and 2018. Upon comparing this figure with the international patent landscape map in Figure 10, the strength of Canadian institutions in Therapeutics and Vaccine Development is apparent as this research area encompasses almost two-thirds of the map.

There are two categories of inventions captured in Figure 17, disease-related inventions and technology-related inventions. The disease related category consists of infections (example: SARS-CoV), diseases (examples: pneumonia, blood disorders, sickle cell disease, bone and pain disorders), virus-receptor mechanisms (example: androgen-receptor modulator), immune responses (examples: innate immunity, anti-inflammatory responses and immunosuppression). The second category involves the underlying technologies used for the development of therapeutic interventions and includes nucleotide sequences, antibody constructs, virus-infected chicken embryos, and preparation of adenoviruses which are used as viral vectors, in addition to involving plant biology. Similarly, for the Rapid Detection & Diagnosis subcategory, the patented inventions related to conjugates, biorecognition and C-reactive proteins are valuable foundational technologies for the pandemic.

Figure 17: Canadian patent landscape map for pandemic mitigation technologies



Therapeutics and Vaccine Development Rapid Detection and Diagnosis Digital Health

CONCLUSION

Given the challenges presented by COVID-19, understanding the context in terms of past innovation offers invaluable insights that can be used to aid in the mitigation of the health impact caused by the current pandemic. This report showcases the areas of strength of Canadian institutions in pandemic mitigation technologies by using a patent search strategy developed in consultation with the National Research Council of Canada. Using this patent search strategy, 11,057 patented inventions were identified globally between 1999 and 2018, of which 8,452 were patented inventions by the institutions. In total, 178, or approximately 2.1% of these 8,452 patented inventions were assigned to Canadian institutions; and relative to international institutions, Canadian institutions ranked eighth in terms of patent activity in this field.
Globally, patented inventions for pandemic mitigation technologies grew, on average, by 17% annually. Unsurprisingly, American and Chinese institutions held the largest patent portfolios in this field and together accounted for more than 50% of the total patented inventions in this analysis. Chinese institutions have made notable headway over the past decade, and in 2018 alone they patented more than twice as many inventions than American institutions, who hold the largest portfolio in this field. It was encouraging to see that the growth experienced by Canadian institutions was almost on par with institutions from leading economies like Germany and Japan between 2009 and 2018.

Over half of the patented inventions in this dataset are related to Therapeutics and Vaccine Development, followed by Rapid Detection and Diagnosis, and Digital Health. The proportion of patented inventions by Canadian institutions in Therapeutics and Vaccine Development inventions is 72%, demonstrating that Canadian institutions have a relative strength in this area when compared to all institutions worldwide. Overall, Canadian institutions were found to have a high relative specialization for pandemic mitigation technologies and their specialization has improved for certain sub-categories of the Therapeutics and Vaccine Development research area over the past decade.

Within Canada, regional clusters of institutions actively patenting were identified for pandemic mitigation related technologies. These hubs take advantage of the emerging talent available and act as catalysts for innovation. The largest clusters in Canada are present in the cities and surrounding areas of Vancouver, Toronto, and Montreal. Manitoba, although not a leader in terms of the volume of patented inventions, is seen to have a number of collaborative patents involving domestic and international players originating from the academic sector.

The patent landscape maps presented in this report visually present the key technology areas in which both international and Canadian institutions are actively patenting. The Canadian patent landscape map is particularly effective in observing Canada's strength in the Therapeutics and Vaccine Development research area, as its coverage captures almost two-thirds of the map. Such insights may allow policymakers to define a policy framework

which leverages this relative strength thereby improving Canada's response in the face of the current pandemic. Furthermore, the Canada innovation ecosystem can benefit from the insights generated from this report by establishing a baseline for innovation in this area and identifying where Canada's strengths lie.

ANNEX A - METHODOLOGY

The term "patented inventions" in this report refers to patent families. A patent family is a collection of similar patent applications filed across multiple jurisdictions. Although there are several different types of patent families, the one considered in this report is the INPADOC extended patent family, which is developed and maintained by the European Patent Office. The earliest patent filed in every patent family is known as the priority patent application. For the purpose of this analysis, priority applications that were filed between 1999 and 2018 were considered.

Patented inventions are classified using a set of International Patent Classification (IPC) and Cooperative Patent Classification (CPC) codes on the basis of the technology areas they relate to. In order to form the dataset for this analysis, patent advisors at the NRC were able to identify a list of IPCs, CPCs and keywords pertaining to pandemic mitigation technologies to form the patent search strategy. In order to limit the number of false positive records captured from certain broad IPCs and CPCs, these codes were used in conjunction with a set of keywords. This patent search strategy was queried against a patent database maintained by Clarivate Analytics known as Derwent Innovation.[ix]

In addition, a small proportion of the dataset was formed using protein sequence numbers and was extracted using Questel's Orbit Intelligence database.[x] During our analysis, these patented inventions were found to be technologically similar to patented inventions pertaining to the Therapeutics and Vaccine Development research area. As a result, these patented inventions were added as a sub-category under Therapeutics and Vaccine Development bearing the name Protein Sequence.

It is important to note that the patent search strategy developed for this report focuses heavily on the three research areas outlined in NRC's *Pandemic Response Challenge Program* and may not be completely representative of the pandemic mitigation technologies. For a copy of the complete patent search strategy along with a list of publication numbers considered for this analysis, please contact cipo-ipresearch-opic-recherchepi@ised-isde.gc.ca.

[ix] https://clarivate.com/derwent/solutions/derwent-innovation/
[x] https://www.questel.com/business-intelligence-software/orbit-intelligence/

ANNEX B - DATA CLEANING

In order to account for the naming convention inconsistencies and spelling errors that are commonly found in any IP dataset, CIPO devotes a significant amount of time to ensure the underlying dataset has as few inconsistencies as possible.

Our data science team leveraged Machine Learning (ML) techniques in its Python script to standardize the data. One of the attributes incorporated into the ML model includes a string comparison metric known as the Jaro–Winkler score, which measures the similarities between two entity names. Another attribute considered is the difference in filing dates of patented inventions bearing the two entity names under consideration. Lastly, the ML model also takes into consideration the number of shared entities between the two entities under consideration. At present, a Random Forest model has been deployed which produces an accuracy of up to 98%. Using this methodology, the entity name having the most information will replace other similar entity names in the dataset.

ANNEX C - INTELLECTUAL PROPERTY CONCENTRATION INDEX

The IPCI used in this report follows a long history of concentration indices applied in many disciplines, such as the Herfindahl-Hirschman Index, Simpson index, Shannon diversity index, and the effective number of parties index. The formula used to calculate the Intellectual Property Concentration Index (IPCI) is as follows:

$$IPCI = s_1^2 + s_2^2 + s_3^2 + \ldots\ldots + s_n^2$$

where s_n is the share of patented inventions held by participant *n*, in fraction.

The value of the index ranges between 1/n and 1. Index values closer to 0 would indicate an industry or technology field has an environment that is more competitive, consisting of a large number of less-active participants. Index values between 0.15 and 0.25 would imply moderate concentration whereas index values in excess of 0.25 would indicate a technology field has an environment that is highly concentrated consisting of a few dominant players. The index can be used to measure the concentration globally amongst the leading countries or within a country to see the competition amongst firms in that country.

ANNEX D - RELATIVE SPECIALIZATION INDEX

The Relative Specialization Index (RSI) is used to better understand a country's strengths in a particular technology area or industry sector. Specifically, it compares the proportion of a country's patented inventions in a particular technology field to the proportion of all of that country's patented inventions to all patented inventions worldwide.
The formula used to calculate the RSI for a particular country is as follows:

$$RSI_{Country} = log_{10}\left[\left(\sum_{1999}^{2018} P_{Country,PMT} \Big/ \sum_{1999}^{2018} P_{World,PMT}\right) \Big/ \left(\sum_{1999}^{2018} P_{Country} \Big/ \sum_{1999}^{2018} P_{World}\right)\right]$$

where P represents patented inventions and PMT stands for Pandemic Mitigation Technologies.

Numerator

The sum total of patented inventions assigned to a particular country's applicants for a particular technology field is divided by the sum total of patented inventions identified globally for that technology field.

Denominator

The sum total of patented inventions assigned to a particular country's applicants is divided by the sum total of patented inventions identified globally across all technology field.

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