IRPP STUDY
August 2019 | No. 72

To Sell or Scale Up: Canada's Patent Strategy in a Knowledge Economy

Nancy Gallini and Aidan Hollis

UNLOCKING DEMAND
FOR INNOVATION

ABOUT THIS STUDY

This study was published as part of the Unlocking Demand for Innovation research program, under the direction of Joanne Castonguay and France St-Hilaire. The manuscript was copy-edited by Clare Walker, proofreading was by Barbara Czarnecki, editorial coordination was by Francesca Worrall, production was by Chantal Létourneau and art direction was by Anne Tremblay.

Nancy Gallini is professor emeritus in the Vancouver School of Economics at the University of British Columbia (UBC). Her research, which has been published in numerous peer-reviewed articles, focuses on the economics of intellectual property, technology licensing and competition policy. She has served on the governing council of the Social Sciences and Humanities Research Council, the Mitacs Research Council, and the editorial boards of the *American Economic Review*, the *Canadian Journal of Economics* and other journals in economics. She was dean of the Faculty of Arts at UBC (2002-10), chair of the Department of Economics at the University of Toronto (1995-2000), and president of the Canadian Economic Association (2016-17).

Aidan Hollis is professor of economics at the University of Calgary and president of Incentives for Global Health, a US-based NGO focused on the development of the Health Impact Fund proposal. His research focuses on innovation and competition in pharmaceutical and electricity markets. He has published many peer-reviewed articles and two books. In 2003-04 he served as the T.D. MacDonald Chair in Industrial Economics at the Competition Bureau. He has provided expert reports and testimony in cases in Federal, Appeals and Supreme Court cases in Canada, and has advised companies and governments.

To cite this document:
Gallini, Nancy, and Aidan Hollis. 2019. *To Sell or Scale Up: Canada's Patent Strategy in a Knowledge Economy.* IRPP Study 72. Montreal: Institute for Research on Public Policy.

ACKNOWLEDGEMENTS

The authors are grateful to Leo Ma for his excellent research assistance and economic insights. We also thank Joanne Castonguay, France St-Hilaire, Mélanie Bourassa Forcier, Corinne Langinier and participants in the IRPP Symposium in May 2018 for many valuable comments.

IRPP Study is a refereed monographic series that is published irregularly throughout the year. Each study is subject to rigorous internal and external peer review for academic soundness and policy relevance.

If you have questions about our publications, please contact irpp@irpp.org. If you would like to subscribe to our newsletter, IRPP News, please go to our website, at irpp.org.

Cover photo: Shutterstock, by Wutzkohphoto.

ISSN 1920-9436 (Online) ISSN 1920-9428 (Print)

CONTENTS

SUMMARY

Canada has many of the right conditions for innovation: a well-educated workforce, strong research institutions, openness to skilled immigration, an active venture capital scene, generous R&D tax credits and access to the large US market. However, as several studies have noted, Canada appears to fall short in exploiting this potential, relative to peer countries. One explanation for this capacity-outcomes gap could be that Canadian researchers, though productive early-stage innovators, are less inclined to scale up and commercialize their new products and processes. Instead, they sell their intellectual property (IP) to foreign entities, forgoing the opportunity to control the exploitation of the patented technologies that they pioneered.

This study by Nancy Gallini and Aidan Hollis examines the role of patents and patent policy in Canadian innovators' decisions to sell their IP rather than continue to develop it in Canada, and the incentives driving this decision.

Drawing from recent literature on the topic, the study highlights the importance of patent ownership – especially for small and medium enterprises (SMEs) – in advancing through the stages of the innovation process from discovery to commercialization. By establishing property rights through patents, innovators are better able to signal their invention's value to potential investors, to ward off competition and to protect themselves from patent trolls.

Patents can, however, be a deterrent to firms scaling up when they are held by other (often large) firms on complementary IP that is essential for their product development. The cost of accessing those patents, through either royalties or legal battles, may simply be too high for small firms to sustain. According to the authors, these cost barriers are particularly relevant in Canada, where SMEs account for a significant share of innovation activity. Moreover, the rise of dominant, vertically integrated US firms that are competitors and potential buyers of Canadian-owned IP assets has increased incentives to sell rather than to scale up.

Based on data on US patents, Gallini and Hollis find that the majority of patents filed by research teams with at least one Canadian inventor are assigned on the date of issue to firms outside Canada or to foreign subsidiaries in Canada. And of the patents that are assigned to Canadian residents, a significant proportion are subsequently sold to foreign entities. While this may be a cause for concern, the authors point out that research investments in Canada by foreign subsidiaries can generate long-term and sustainable benefits for Canadians. Such investments can enhance innovative capacity in Canada through the development of entrepreneurial expertise and scientific infrastructure, especially relative to an alternative scenario that might involve the exodus of Canadian talent.

Still, these structural and institutional features of the innovation environment have important policy implications. For a small, open economy such as Canada's, strengthening intellectual property laws is not likely to have much impact on scaling up activity.

More important to inventors is the ability to obtain and retain ownership of international patents in order to operate in global markets.

However, as patent ownership affects the likelihood that innovators will commercialize their ideas and scale up their operations, policies that reduce the uncertainties of exploiting IP – such as educating innovators on the value of patent ownership, reducing the cost of searching technical literature and existing patents for prior art that would undermine patent validity and eliminating bottlenecks in accessing global markets due to patent trolls and other litigation – could tip the balance toward scaling up and increase the return on research investment. On the other hand, policies that raise the cost of IP sales (for example, a tax on international IP transfers) could be counterproductive to innovation activity in Canada.

Promising measures aimed at promoting better management of our IP assets are currently being implemented as part of the federal government's Intellectual Property Strategy. But, as Gallini and Hollis conclude, further policies and incentives to support patent retention will be required for Canada to achieve greater returns on its innovation potential.

RÉSUMÉ

Le Canada réunit beaucoup d'éléments propices à l'innovation : main-d'œuvre instruite, solides établissements de recherche, ouverture aux immigrants qualifiés, marché dynamique du capital-risque, généreux crédits d'impôt pour la R-D et accès à l'immense marché américain. Mais comme le montrent plusieurs études, il exploite ce potentiel avec moins de succès que de nombreux pays comparables. Ce décalage entre capacités et innovation pourrait s'expliquer par la faible propension de nos chercheurs, pourtant très innovants à l'étape de la R-D, à valoriser et commercialiser leurs nouveaux produits et processus. Ils choisissent plutôt de vendre leur propriété intellectuelle (PI) à des entités étrangères, renonçant ainsi à exploiter les technologies brevetées qu'ils ont inventées.

Nancy Gallini et Aidan Hollis examinent dans cette étude le rôle des brevets et des politiques dans la valorisation des innovations et tentent de déceler ce qui incite les innovateurs canadiens à vendre leur PI au lieu de poursuivre leur développement au pays. S'appuyant sur de récentes recherches sur la question, les auteurs soulignent l'importance de détenir un brevet, surtout chez les petites et moyennes entreprises (PME), pour franchir les étapes du processus d'innovation menant de la découverte à la commercialisation. En établissant leurs droits de propriété au moyen de brevets, les innovateurs sont mieux en mesure de faire valoir leurs inventions auprès d'éventuels investisseurs, de contrer la concurrence et de se protéger des chasseurs de brevets.

Les entreprises peuvent toutefois hésiter à poursuivre le développement de leurs inventions si d'autres sociétés (souvent importantes) détiennent des brevets sur des éléments de PI complémentaires qui sont essentiels au développement de leurs produits.

Le prix à payer pour accéder à ces brevets, par des redevances ou alors des batailles juridiques, est souvent trop élevé pour une petite entreprise. Selon les auteurs, cet enjeu est particulièrement important au Canada, où les PME assurent une part considérable des activités d'innovation. De plus, l'essor de puissantes sociétés américaines verticalement intégrées, à la fois concurrentes et potentielles acheteuses d'actifs de PI canadiens, vient renforcer l'incitation à vendre plutôt qu'à valoriser.

À l'examen des données sur les brevets américains, les auteurs ont constaté que la majorité des brevets déposés par des équipes de recherche comptant au moins un inventeur canadien sont attribués au départ à une entreprise à l'extérieur du Canada ou à une filiale étrangère au Canada. De plus, une forte proportion des brevets attribués à des résidents canadiens sont par la suite vendus à des entités étrangères. Certains pourraient s'en inquiéter, reconnaissent les auteurs, mais les investissements en recherche effectués au Canada par des filiales étrangères peuvent produire des avantages durables au pays. Ils peuvent ainsi renforcer notre capacité d'innovation en favorisant le développement d'une expertise entrepreneuriale et d'une infrastructure scientifique, alors que d'autres scénarios pourraient susciter l'exode de talents canadiens.

Les aspects structurels et institutionnels de l'environnement d'innovation ont tout de même d'importantes implications en matière de politiques. Pour une petite économie ouverte comme le Canada, le renforcement des lois sur la propriété intellectuelle aurait sans doute peu d'effet sur les activités de valorisation. Il est plus important pour les inventeurs d'obtenir et de conserver la propriété de brevets internationaux afin de pouvoir opérer sur les marchés mondiaux.

Mais comme la détention de brevets influe sur la décision des innovateurs de commercialiser leurs idées et de développer leurs activités, des mesures visant à réduire les risques financiers liés à la PI pourraient les inciter à aller de l'avant et ainsi améliorer le rendement des investissements en recherche. On pourrait, par exemple, mieux informer les innovateurs sur l'importance de détenir des brevets, réduire les coûts de recherche de publications techniques et de brevets antérieurs susceptibles d'invalider leurs inventions, ou éliminer les goulots d'étranglement créés par les chasseurs de brevets et par d'autres pratiques litigieuses qui bloquent l'accès aux marchés mondiaux. En revanche, les mesures qui font augmenter le prix de vente de la PI (par exemple une taxe sur les transferts internationaux de PI) pourraient se révéler contre-productives et nuire aux activités d'innovation canadiennes.

Des mesures prometteuses visant une meilleure gestion de nos actifs de PI sont actuellement mises en œuvre dans le cadre de la Stratégie en matière de propriété intellectuelle du gouvernement fédéral. Mais pour rentabiliser pleinement son potentiel d'innovation, le Canada devra élaborer d'autres politiques et mesures incitatives qui favorisent la rétention de brevets, concluent Gallini et Hollis.

INTRODUCTION

The health of our economy relies to an ever-increasing extent on technological advances, whether in medicine, cars, computers or food production. Innovation is the key to improving standards of living and protecting the environment. Consequently, a priority of the Canadian government and governments worldwide has been to identify a mix of policies, including policies on intellectual property (IP), that will inspire and support greater investment in innovation activities.

Patents – IP rights on the use of inventions underlying new products and processes – have become essential in most areas of innovation. The technology that supports almost everything that we buy is often patented, enabling innovators to earn a share of the value created by their innovation. Unfortunately, the evidence suggests that Canada may not be making the most of its innovative capabilities. Several studies, such as a 2018 report from the Council of Canadian Academies (CCA 2018), have examined Canada's successes and shortcomings in innovation, uncovering a paradox: although Canada appears to be competitive with peer countries in its capacity to invent (for example, number of scientists, access to venture capital), it falls short in innovation outputs (for example, patents, productivity).[1] Understanding why Canada's capacity to invent is not translating more effectively into increased innovative output is central to these studies.

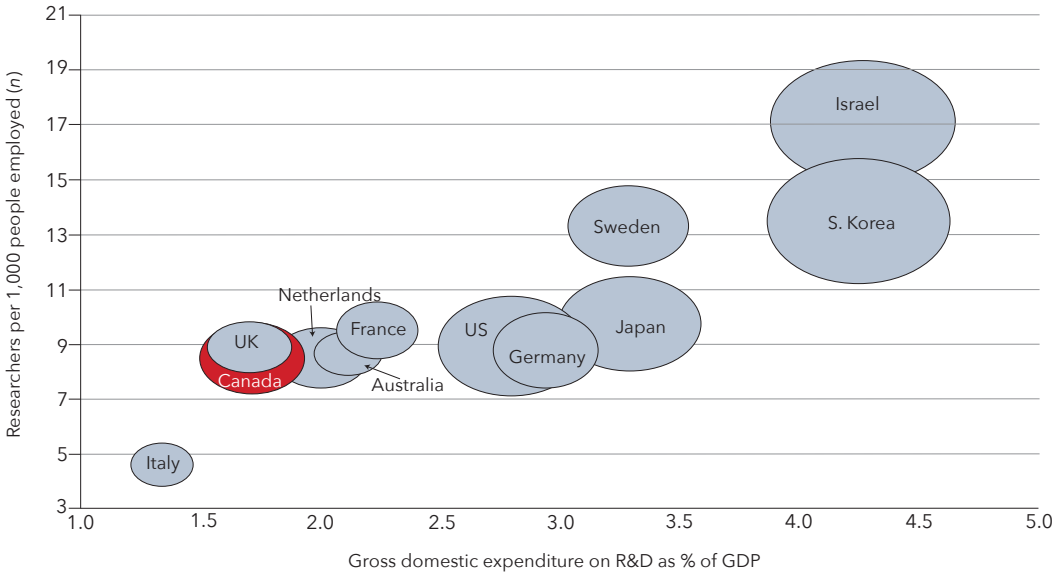
Figure 1 illustrates this Canadian paradox. It shows the number of researchers as a share of people employed in peer OECD countries against R&D expenditures as a percentage of GDP;[2] the size of the bubbles reflects the number of patents granted by the US Patent and Trademark Office (USPTO), scaled by GDP. As noted above, Canada is competitive in scientific human capital but falls short in both total R&D expenditures and patent output. One might conclude from this figure that low R&D spending is the cause of low innovation output: that is, scientists are not receiving sufficient funding to innovate. Indeed, R&D investment is a necessary input into research output. This observation, however, may also represent a reverse causality: low R&D investment reflects a disproportionate focus on early stages of innovation, rather than on patent-rich product development and commercialization.

The latter point is consistent with the CCA report's observation that Canadian innovators engaged in early-stage research often sell their IP abroad rather than scaling up and commercializing their new products and processes. In raising this as a social concern, the report notes that IP sales from early-stage research enrich Canadian inventors and provide funds for future investment; however, further employment and productivity gains from scaling up the domestic operation (assuming this can be done efficiently) are potentially forgone. Moreover, foreign recipients of the IP may be the beneficiaries of those gains. Therefore,

[1] See also Schwanen and Wyonch (2018); Advisory Panel for the Review of Federal Support for Fundamental Science (2017), known as the "Naylor Report"; Science, Technology and Innovation Council (2015); and Jenkins et al. (2011).

[2] The selection of peer countries is based on population and per capita GDP, with the US added for comparison.

Figure 1. The relationship among patenting in the US, R&D expenditures and the number of researchers, selected countries, 2016



Sources: OECD, Main Science and Technology Indicators Database, http://oe.cd/msti; US Patent and Trademark Office, USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm; World Bank national accounts data and OECD National Accounts data files, GDP (constant 2010 US$), https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?.
Note: Bubble size varies according to number of patents per $100 billion GDP.

public funds that support the early-stage research may end up providing a foundation for profits and tax revenues in other countries. Unless innovative start-ups receive a fair return on their IP assets, Canadian taxpayers are effectively subsidizing foreign buyers. Another reason – and one that we are concerned with in this study – is that if Canadian researchers sell their IP assets, future production or research in related areas may be impeded by the new owners of the patented technologies pioneered by Canadian inventors.[3]

Among the barriers to scaling up, the CCA (2018) points most notably to a shortage of managerial skills and IP expertise.[4] In this complementary analysis, we further explore barriers to scaling up through the lens of patent systems. In particular, we ask the following question: *What role do patent rights play in the decisions of Canadian innovators to "sell versus scale up"?*

We focus on the sequential and cumulative nature of technological innovation and its implications for small and medium-sized enterprises (SMEs), which produce over

[3] James Hinton, an IP lawyer presenting at the House of Commons Standing Committee on Industry, Science and Technology in 2017, cautioned: "It's not only that we don't protect, but we also allow the technology that we have protected to be raided by foreign firms…When a Canadian company is looking to develop similar technology, the foreign tech can prevent that Canadian company from practising that technology, or force them to take a licence. We are essentially encouraging a system whereby Canadian companies must then license back Canadian taxpayer-funded IP from the big foreign technology competitors. Instead of reinvesting in Canadian R and D, Canadian companies are paying IP royalty fees" (June 6, https://www.ourcommons.ca/Content/Committee/421/INDU/Evidence/EV9015393/INDUEV65-E.PDF, 4).

[4] See also Conference Board of Canada (2018) and Plant (2017) for related discussions.

40 percent of innovation in Canada. Recent empirical analysis in the US indicates that patents are important to SMEs in developing innovation but can be a deterrent when owned by large firms from which they must license IP. Moreover, because of the complexity of modern technologies, patent claims can overlap, leading to potentially costly litigation, especially for SMEs that do not have large patent portfolios to negotiate with if sued for infringement. That is, empirical findings support the importance of IP "ownership" for the innovative capacity and scale-up potential of SMEs in the knowledge-based economy.

To see whether and how these lessons from the literature apply to Canada, we examine data on both Canadian "IP inventiveness" and "IP ownership." Data from the USPTO reveal that many patented inventions with contributions from Canadian inventors do not lead to commercialization and scale-up in Canada.[5] In fact, the majority of US patents filed by research teams with at least one Canadian inventor are assigned on the date of issue to firms outside Canada – hereafter referred to as "foreign firms" – or foreign subsidiaries in Canada. From a smaller sample, we also find that, with those patents assigned to Canadian residents, many of the patent owners do not go on to develop the IP into a marketable product, scale up their operation in Canada and commercialize the product. Rather, they sell their assets, including their IP, to foreign entities with the infrastructure and knowledge to exploit the invention. These observations are consistent with Canada being rich in scientific human capital but underperforming in R&D spending and patents.

It is important to note the limitations of our analysis, which focuses on patentable products and processes. Patented inventions represent only a subset of innovation activity in Canada. A large number of innovations are protected by other forms of IP, such as trademarks, copyrights or trade secrets, or – importantly – are free for others to use through open source. For example, nonpatentable innovations may include business improvements in inventory systems and financial and management processes that also have a significant impact on productivity and national income in Canada. Nevertheless, patents closely correlate with other measures of innovation (Shambaugh, Nunn and Portman 2017), and are considered to be the linchpin for innovative firms seeking capital and growth opportunities in a global knowledge-based economy (Farre-Mensa, Hegde and Ljungqvist 2017). In attempting to understand if and how patents affect incentives to advance in the innovation process, our study provides complementary insights to a growing literature on factors driving innovation in Canada.[6]

We argue that while property rights on intangible assets are fundamental to a well-functioning innovation market, there is little evidence to suggest that strengthening patents in a small open economy such as Canada would have much impact on scaling up innovation activity domestically (Blit 2017). Of greater importance to Canadian

[5] We use US patent data because the US has the largest number of Canadian patent applications in the world and, arguably, is a primary market for inventors aspiring to scale up, commercialize and expand their global reach.

[6] Our study also builds on Greenspon and Rodigues (2017), Barnett (2017) and Plant (2017).

inventors is obtaining and retaining ownership of international patents.[7] Accessing these complex and often litigious markets requires knowledge of international patent systems and new strategies for operating in them. Toward that objective, we analyze the role that patents play in encouraging (or discouraging) scale-up and commercialization of Canadian-invented IP. In particular, we consider how changes in US patent policy and a litigious environment may have tipped the balance in favour of selling rather than holding patents. This incentive to sell is further supported by US firms' demand for Canadian IP, owing to their greater degree of vertical integration as well as the strong trading ties and cultural affinity between the two countries.

Finally, we examine various policies, proposed or currently in place, aimed at promoting the creation and better management of IP resources in Canada, including the recently announced Intellectual Property Strategy,[8] against the objective of maximizing Canadian incomes.[9]

THE INNOVATION PROCESS

What are patents?

According to Canada's *Patent Act*, a patent is a property right, granted by the government, that gives the inventor "the exclusive right, privilege and liberty of making, constructing and using the invention and selling it to others to be used, subject to adjudication in respect thereof before any court of competent jurisdiction."[10] As Lemley and Shapiro (2005) note, such a property right is probabilistic in that the breadth of the patent (the claims protected) and its strength (enforcement of the right) can be contested or defended in court on grounds of invalidity or infringement.

A patent is granted if it satisfies the standards of novelty, nonobviousness and usefulness. An invention is novel if it is not part of prior art; not obvious if the "inventive step" is sufficiently large that a "person having ordinary skill in the Art" would not have found it obvious; and useful if it has the promise of generating a product or process.[11]

Patents are domestic in nature. Having a patent on an invention in Canada does not offer any ability to control the use of the invention in other countries. Therefore, valuable inventions tend to be patented in many countries, as facilitated by the Patent

[7] Balsillie (2018) suggests that Canada's record of "commercializing its ideas won't change unless we build proper infrastructure to help our entrepreneurs succeed on the global stage…We need a strategy to advance our prosperity beyond the incomplete mantra of greater domestic IPR protection and open borders because these policies have not contributed to the growth of an indigenous innovation economy."

[8] See Innovation, Science and Economic Development Canada (2018) for an overview of the IP Strategy.

[9] To guide us in our analysis, we adopt the objective of increasing returns from investment on innovation to the Canadian economy in the form of income (for example, employment, profits, taxes) to Canadian residents.

[10] Canada, *Patent Act*, R.S.C., 1985, c. P-4, s. 42, https://laws-lois.justice.gc.ca/eng/acts/P-4/index.html.

[11] See Canadian Intellectual Property Office (n.d.) for a presentation of patent standards. The set of patentable subject matter is described in the US Code (section 101, title 35): "Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof may obtain a patent therefor, subject to the conditions and requirements of this title."

Cooperation Treaty. Patenting is also costly; typically filing and attorney's fees add up to more than $10,000. The result is that patents are often filed only in the largest, most important jurisdictions, such as the US, where the potential economic gains from exploiting the patent are the greatest. For instance, approximately twice as many patents listing a Canadian inventor are granted in the US as in Canada.

The primary economic justification for awarding property rights on intangible assets is to encourage investment in their development and disclosure. Developing new products and processes can be costly. Having temporary property rights over the use of an invention can create an incentive to undertake that costly investment. Moreover, in protecting property rights on an invention, patents enable owners to exploit the economic value of their invention, for example through licensing their inventions to adopters who can then use them in downstream production or to researchers who can build upon them toward further discoveries.

Granting property rights to secure these economic benefits, however, comes at a cost of restricted access – in the form of monopoly prices, royalties or potential litigation costs – to three categories of users: consumers, adopters and follow-on researchers. A well-balanced IP system trades off the benefits of innovation against the costs of reduced access to users. If the patent system is overreaching, it may – counterintuitively – *reduce* innovation by creating barriers to follow-on research in new ideas.[12] We highlight these costs here not for the purpose of analyzing "optimal" patent policy, but rather to identify features of the patent system that could affect decisions by producers to adopt state-of-the-art IP, or by inventors to take their IP to the next stage of commercial exploitation.

Stages of innovation and exploitation

According to the Oslo Manual (OECD 2018b, 32), innovation refers to "a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)." Within the broad set of innovations encompassed by this definition, we restrict our attention here to those that are patented. Because inventions that are patented have had to demonstrate their "usefulness," they therefore have potential for commercial application.

To better understand the scale-up decisions facing Canadian innovators, we find it useful to make a distinction between the different "stages" of the innovation process, starting from the invention or discovery of a patentable idea, to product development and commercial exploitation, and ultimately to improving and building upon IP assets. We give examples of innovation at each stage:

Stage 1: Develop and patent an invention (for example, identify a target for a drug with expected demand to treat a specific disease)

[12] See, for example, Dickinson and Rhys (1927) and Mokyr (1990) for a discussion of how the Watt patents delayed further progress and the introduction of improvements in steam engine technology.

Stage 2: Develop a marketable application (for example, develop and perform Phase 1 clinical trials to test a drug that addresses that target)

Stage 3: Scale up domestically and commercialize application locally and globally (for example, complete Phase 2 and 3 clinical trials, obtain regulatory approval, evaluate market demand and commercialize the new drug)

Stage 4: Make ongoing innovation a core competency of a firm (for example, respond to demand in related markets by extending from one commercialized invention to many)

Many Canadian firms in the knowledge-based economy have gone through one or more of these stages. Box 1 presents concrete examples of inventions and the challenges involved in moving from one stage to the next: developing the invention into a marketable product (stages 1 to 2), scaling up and bringing the product to market (stages 2 to 3), or becoming a sustainable innovative organization (stages 3 to 4). To highlight the relationships between stages, we use examples related to the development of pharmaceuticals. However, the stages of commercial exploitation also apply to other innovative industries.

As noted earlier, Canadians appear to have a comparative advantage in early-stage research (stages 1 and 2), but are less effective in scaling up, commercializing and competing in the global arena (stages 3 and 4). In considering the barriers to scaling up

Box 1: Examples of Stages of Commercial Exploitation in Pharmaceuticals

Stage 1: Researchers at the University of Alberta identified antibodies that can be used to recognize the hENT1 gene. Patients with high levels of expression of this gene can be treated more effectively for certain cancers using specific therapies; thus a test to identify hENT1 accurately is significant. The researchers, however, rather than developing this patented technology into an application for commercialization (stage 2), licensed it to DueNorth Biodev (2018), a biotech company focused on "bridging the gap between research and market entry."

Stage 2: Tevosol, founded by academic researchers at the University of Alberta, attracted venture capital funding to develop a working prototype of the Ex-Vivo Organ Support System into a marketable technology for improving the viability of organ transplants. This technology appears ready to be commercialized. Whether the owners of the IP will commercialize its patented technology or sell it to a larger, better capitalized medical services company (stage 3) has not been decided.

Stage 3: A spin-off from the University of British Columbia, QLT developed Visudyne, a successful drug for the treatment of age-related macular degeneration. The company, however, was unable to parlay this success into sustained growth after the patent expired. QLT commercialized the drug while licensing it to pharmaceutical companies with production capacity. The company's share price peaked at $119 in 2000 based on the success of Visudyne sales, but QLT was unable to transform itself into a multidrug company (stage 4); today the share price has fallen to under $2, with a market capitalization of about $25 million. In many cases, Canadian companies such as QLT are acquired by larger firms that are better able to achieve efficient scale and scope and reallocate capital between products.

Stage 4: With a market capitalization of over $1 billion, Knight Therapeutics offers an interesting example of stage 4 of the innovation process. The company in-licenses mostly experimental drugs from small biotech companies and then markets and distributes them in Canada and abroad. In effect, it specializes in the last steps of product development, after acquiring control of relevant patents, and now has a portfolio of about 20 drugs.

Sources: TEC Edmonton (2017a,b); Zehr (2018); Funding Universe (n.d.); and Knight Therapeutics (n.d.).

in Canada, the CCA (2018) offers three possible explanations: (1) "lack of managerial experience and IP skills" necessary for start-up firms to scale up and enter global markets; (2) Canada's relatively generous R&D tax credits for SMEs, which make Canada "a better place to start a technology company than to grow one"; and (3) Canada's close trade relationship with the US, which incentivizes Canadian exporters to provide "intermediate goods or services…as part of integrated, continental value chains" rather than conduct R&D in new products and processes (156 and 167).[13]

We consider a fourth explanation: that global IP rights, while important for SMEs to garner the capital required to conduct their R&D, can potentially raise the costs of engaging in further research when the IP rights pertain to essential inputs owned by other firms. In that case, they must secure licences on these patents to engage in further R&D, or to scale up and commercialize their marketable product/process.

CANADA IN GLOBAL MARKETS: INSIGHTS FROM ECONOMIC THEORY

In this section, we highlight significant legislative and legal changes to the US patent system. We also identify results from the recent economics literature that may be relevant in understanding Canada's innovation landscape and, in particular, the decisions of Canadian inventors to sell their IP rather than develop it further.

Changes to the US patent system

Since the 1980s, the US patent system has undergone several fundamental changes that have dramatically altered the nature of IP and its protection, and patentees' strategic behaviour in the US and around the world. One such change is the expansion of the set of patentable subject matter to include genetically modified bacteria,[14] transgenic animals,[15] gene sequences, software[16] and business methods.[17] This expansion blurred the line between things that are patentable and things of nature or abstract ideas that are ineligible subject matter.[18]

[13] The CCA's 2013 report identifies two other explanations for Canadian firms not scaling up: (1) difficulty in accessing university inventions or aligning priorities, and (2) difficulty in securing adequate venture capital (15-16). However, its 2018 report notes that OECD data show considerable improvement in these areas (CCA 2013, 2018).

[14] See *Diamond v. Chakrabarty*, 447 U.S. 303 (1980).

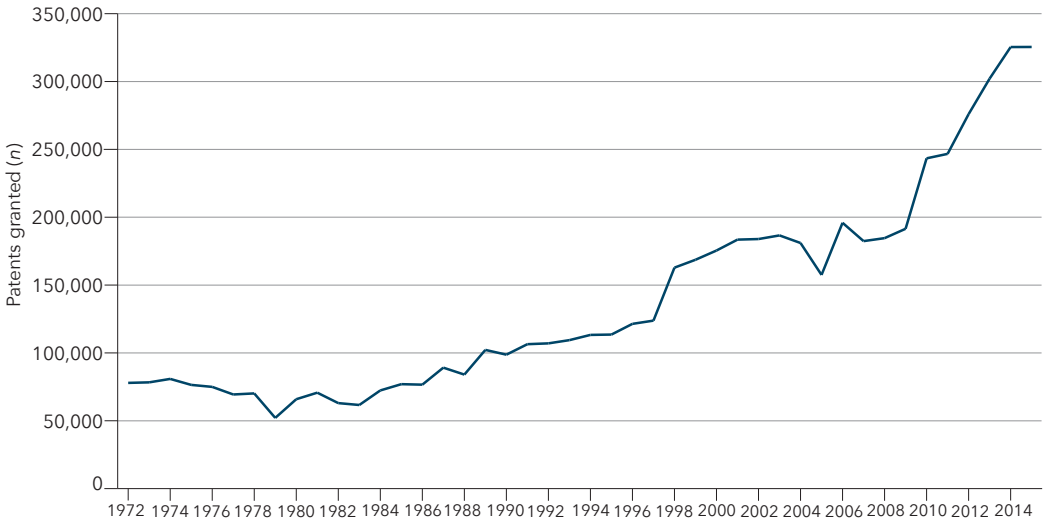
[15] In 1988, Harvard University received a US patent on the Oncomouse, a genetically engineered mouse that is susceptible to cancer.

[16] Patents have been awarded on software in the US since the early 1970s, but three cases between 1972 and 1981 established a framework for evaluating patent eligibility: *Gottschalk v. Benson,* 409 U.S. 63, 64 (1972); *Parker v. Flook*, 437 U.S. 584, 586 (1978); and *Diamond v. Diehr*, 450 U.S. 175, 192 (1981). In *Diamond v. Diehr*, the Court upheld the patent rights on a process invention, emphasizing the physical rather than mathematical or abstract features.

[17] See *State Street Bank v. Signature Financial Group*, 47 USPQ2d 1596 (CAFC 1998).

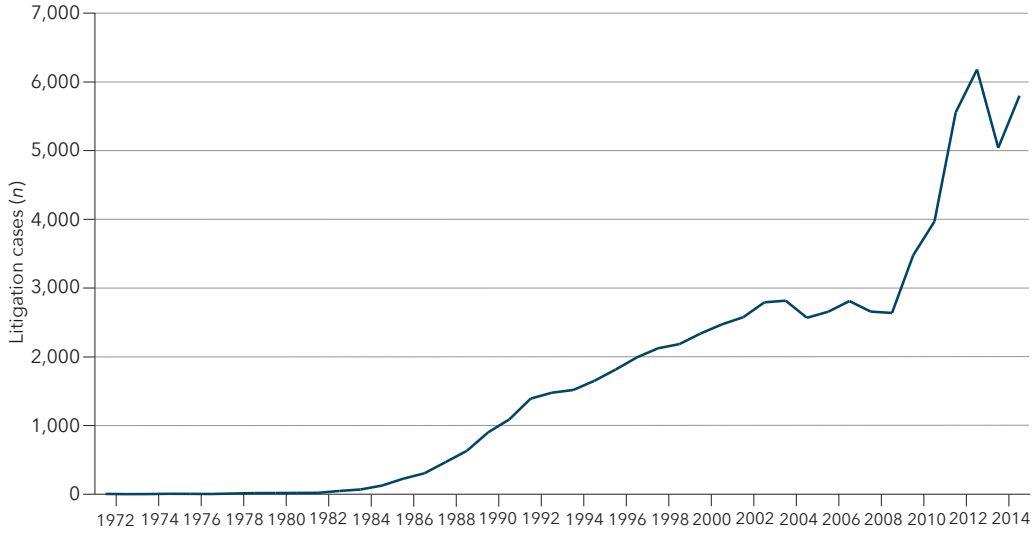
[18] See, for example, Gallini (2002, 2017), Jaffe and Lerner (2004), Bessen and Meurer (2008) and Boldrin and Levine (2008).

Figure 2. Patents granted by the US Patent and Trademark Office, 1972-2015



Source: US Patent and Trademark Office, "U.S. Patent Activity Calendar Years 1790 to the Present," "Annual U.S. Patent Activity Since 1790," https://www.uspto.gov/web/offices/ac/ido/oeip/taf/h_counts.htm.

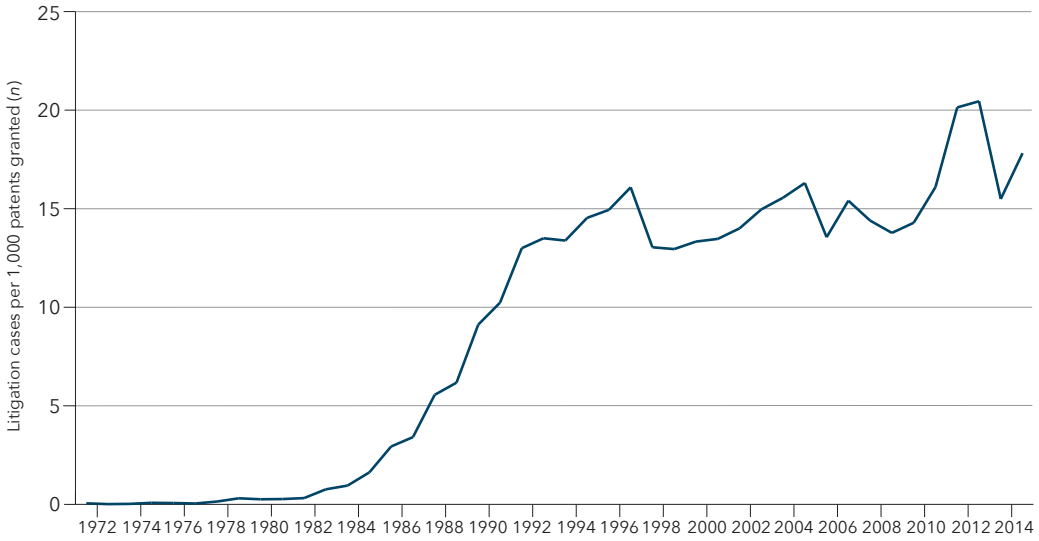
Figure 3. US patent litigation cases, 1972-2015



Source: US Patent and Trademark Office, "Patent Litigation Docket Reports Data," https://www.uspto.gov/learning-and-resources/electronic-data-products/patent-litigation-docket-reports-data.

Also significant was the formation in 1982 of the centralized US Court of Appeals for the Federal Circuit, which specializes in patent appeal cases. The probability of patentees prevailing in infringement and invalidity appeals, as estimated by Henry and Turner (2006), increased significantly following the establishment of this court. Not surprisingly, these changes resulted in an increase in patents and litigation, starting in the late 1980s, as illustrated in figures 2 and 3.

Figure 4. US patent litigation cases as a proportion of US patents granted, 1972-2015



Source: US Patent and Trademark Office, "Patent Litigation Docket Reports Data," https://www.uspto.gov/learning-and-resources/electronic-data-products/patent-litigation-docket-reports-data.

While patent litigation effectively kept pace with patenting in the early 1980s, and again after the mid-1990s, it increased sharply from the mid-1980s to the mid-1990s, as illustrated in figure 4. At that time, the sudden rise in applications on new subject matter overwhelmed both the USPTO, which lacked adequate expertise in these areas (Jaffe and Lerner 2004), and the legal system, which faced a surge of infringement and validity cases. Although litigation cases have not increased disproportionately relative to patents since then, the sheer volume of cases heralded a new set of challenges for the courts to adjudicate regarding complex subject matter, claims of patent infringement and invalidity, and patent trolling (discussed below).[19]

The Canadian patent system is similar to that of the US in many ways, including patent duration and standards.[20] Unlike the US, however, Canada has no appeals court with judges specializing in patent cases; rather, all IP appeals, both patent and nonpatent ones, are heard by the Federal Court of Appeals. Litigation is much less frequent in Canada, perhaps owing in part to the absence of "forum shopping" for the friendliest court.[21] As in the US, software and business method patents are not excluded from

[19] Patent filings have increased worldwide over the past decade. China had the most dramatic increase, of 500 percent, from 2006 to 2016. In contrast, applications at the USPTO increased by only 32 percent, whereas patent applications at CIPO actually declined by 17 percent (Dutta, Lanvin and Wunsch-Vincent 2018).

[20] As noted below, the U.S. Chamber of Commerce has argued that Canadian patent protection is inadequate, relative to the US. The two systems differ in the statutory language of patent law, in how courts interpret that language and in the application of and enforcement of standards. For example, for several years the Canadian courts required patentees to demonstrate a higher standard of utility than is common in other countries. The Supreme Court of Canada, however, overturned this standard in 2017 (*AstraZeneca Canada Inc. v. Apotex Inc.*, 2017 SCC 36, [2017] 1 S.C.R. 943). For more information on the Canadian patent system, see Perry and Currier (2014).

[21] Since most patent cases in Canada are tried in the single Federal Court, there is little incentive for a plaintiff to search for a friendly court that might increase its chances of winning a validity or infringement case.

eligible subject matter, but they are becoming more difficult to obtain following recent Canadian Patent Appeal Board cases.[22] Gene patents were contested in Canada, but the case was settled out of court. Therefore, the eligibility of gene patents has not been fully resolved,[23] in contrast to the US, where the US Supreme Court ruled against the eligibility of gene patents in the Myriad Genetics case in 2013.[24]

Patent thickets and litigation

It is now well recognized that innovation is a cumulative process, in which new technologies build continually and sequentially upon discoveries that preceded them (Scotchmer 1991). Since modern technologies tend to be modular – composed of hundreds or even thousands of components, or are improvements over previous generations, many of which are patentable – new entrants into the market are forced to license multiple patents or face patentees' threats alleging infringement. This is the "anti-commons" problem, in which too many property rights owners inefficiently reduce output (Heller and Eisenberg 1998; Rai 2007). Moreover, with uncertainty in subject matter eligibility, many patented components, even those appearing to be unrelated, may have "overlapping" claims. Together, the anti-commons problem and overlapping claims can create a "thicket" of patents that innovators must disentangle to "move to the next level" of development.

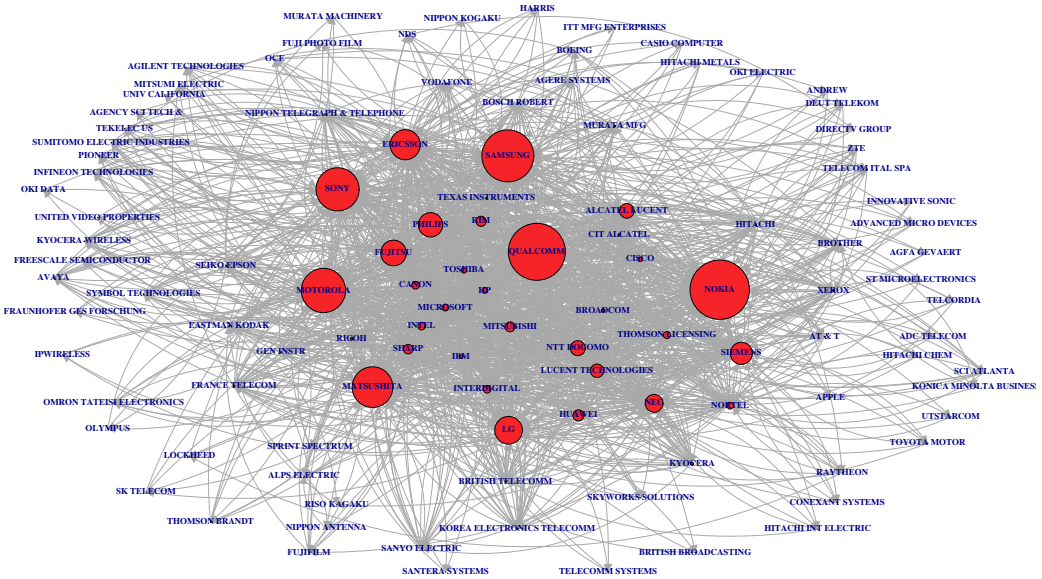
In other words, patent rights on modern technologies typically extend beyond the patented component to innovations that require it or next-generation improvements that build upon it. Therefore, researchers aspiring to develop an invention into a marketable application must engage in a costly process of identifying patents that might be infringed and incur significant costs of negotiating licences with multiple patentees. If threatened with injunctions or costly legal battles, the researchers may simply choose to abandon their research projects altogether (Lerner 1995; Feldman and Lemley 2015, Mezzanotti 2015).

An example of an emerging patent thicket is the explosion in US patent applications mentioning the word "CRISPR." As of July 2018, according to the USPTO patent database, 2,451 patent applications were using this important genetic manipulation tool. Any firm trying to develop new uses for CRISPR would need to examine this large set of technologies to ensure that it did not infringe.[25]

A second example of a patent thicket occurs in telecommunications, considered an area of comparative strength for Canada (CCA 2018). Figure 5, constructed by Hall, Helmers and von Graevenitz (2015, 2016) with data from the UK, illustrates the thicket, where the size of a company's bubble is proportional to the size of its patent portfolio and the lines between companies indicate potentially overlapping patent claims.

[22] See, for example, Rush, Chin and Kaikai (2016).
[23] The Children's Hospital of Eastern Ontario brought a case against US-based Transgenomic Inc. for the genes related to the inherited disorder QT syndrome and the diagnostic testing of it; see Ubelacker (2016).
[24] *Association for Molecular Pathology v. Myriad Genetics, Inc.* 569 U.S. 576 (2013). While the court ruled that genes are not eligible for patents, processes for isolating and manipulating genes may be eligible.
[25] Gene editing technologies such as CRISPR are eligible for patents; see, for example, J. Wolfe (2018).

Figure 5. A patent "thicket": the global telecommunications industry



Source: Hall, Helmers and Graevenitz (2016). Reproduced with permission.

As the figure reveals, large multinational firms with sizable patent portfolios dominate the thicket. These accumulated patents are effective strategic tools for curtailing legal battles with out-of-court cross-licensing agreements.[26] Therefore, firms in a thicket are compelled to stock up on patents as a strategic defensive strategy if they hope to compete, which in turn thickens the thicket. For a small firm with only a handful of patents to defend itself, the prospect of entering this legal morass and competing with multinational firms, equipped with powerful patent artilleries, deep pockets and substantial in-house legal capacity, can be daunting.

The aggressive acquisition and assertion of patent rights is reminiscent of two cases featuring Canadian firms at their centre. First, upon the bankruptcy of Nortel, the "Rockstar group," including Apple, Microsoft and Research in Motion (RIM), paid $4.5 billion for Nortel's patents in 2011 for the express purpose of using them (in defence) against Google. The second case involved RIM, which was threatened in 2005 with an injunction by NTP, a patent troll (a nonpractising entity), whose primary asset was its patent portfolio.[27] During trial, RIM attempted to show that the patents were invalid, in that the wireless e-mail system claimed in NTP's patents was in the public domain prior to NTP's patents. However, RIM's efforts failed; after a legal battle, RIM relented and paid NTP $612.5 million. Trolls are attracted to thickets and populate them by buying up patents without engaging in R&D or production, and by threatening unsuspecting innovators to extract lucrative settlements. In this sense, patents have become strategic tools that have value distinct from the technology they are protecting.

[26] Approximately 95 percent of patent infringement suits are settled before a court judgment is reached (Lanjouw and Schankerman 2004).

[27] Recent literature examines whether nonpractising entities provide a positive benefit in enforcing patents or raise uncertainty and legal costs that discourage research activity. For example, see Bessen, Ford and Meurer (2012), Lemley and Feldman (2016) and Feng and Jaravel (2016).

Thickets are more prominent in some industries. Recent empirical literature (Galasso and Schankerman 2015, 2018; Williams 2013; Murray and Stern 2007; Sampat and Williams 2019) finds that thickets are particularly dense in two technology areas in which Canada has a comparative advantage: computers and communications.[28] Not surprisingly, trolls also tend to occupy these areas (Feng and Jaravel 2016). Galasso and Schankerman (2015) show that patents can discourage follow-on research in these areas, but only in situations in which small firms require essential patents owned by large firms to develop a product.[29] However, in their 2018 paper, they also find that patents held by small firms are valuable to follow-on research in a technology space occupied by large firms where patents are used as collateral. This suggests that patents give small firms a competitive edge in a market with large firms, where they can expect to extract larger royalties. Moreover, the presence of large firms may be an indication of potential buyers for an improved patent, giving further impetus to engage in follow-on research. Sampat and Williams (2019) conduct a related empirical analysis in the case of gene patents and find no significant impact of patents on subsequent research. Finally, patents can signal value of the inventions to venture capitalists, making it easier to obtain necessary funding for further development. According to Farre-Mensa, Hegde and Ljungqvist (2016, abstract), "patents act as a catalyst that sets start-ups on a growth path by facilitating their access to capital."

We draw from this literature three major take-aways that can help inform the question posed in this study as to whether and how patents affect incentives to sell rather than scale up and commercialize:

- Patents on research tools and essential inputs are more likely to block firms engaged in later-stage research when:
  - innovation is in a thicket industry (for example, telecommunications and computers) where negotiation and litigation costs of getting sued are high, although this observation does not appear to apply to gene patents; or
  - the innovator is a small firm engaged in follow-on research requiring large firms' patents, but does not have a significant portfolio of patents to trade.

- Small firms engaged in follow-on research benefit from owning patents when they operate in a market with large firms and their patents are used as collateral.

- Patent trolls tend to operate more intensely in thicket industries and can hamper research efforts by targeted firms.

These results are especially relevant in the Canadian context since SMEs are responsible for a significant proportion of Canada's R&D activity. In 2013, SMEs accounted for about 42 percent of industrial R&D spending (Industry Canada 2016). As noted, patents are particularly important to SMEs, both those intending to scale up domestically and compete in the market, and those aspiring to sell their IP. Indeed, according to Eckert, Langinier and Zhao (2018), smaller firms in Canada are more likely to rely on patents (in both Canada and the

[28] This result on patent thicket areas is consistent with results in Hall, Helmers and von Graevenitz (2015).
[29] See also Gallini (2017).

US) than larger firms. Moreover, given the presence of patent thickets in technology areas of comparative advantage for Canada, SMEs operating in these areas without patents on essential inputs could face prohibitive litigation costs or, alternatively, pay high licensing royalties, which in turn raise their marginal costs of scaling up and reduce their competitive edge.

These factors may help explain why many Canadian owners of US patents fail to retain and develop them in Canada. High-tech inventions require a multitude of complementary patents, many which are owned by large multinationals. In these circumstances, small firms engaged in follow-on research may face legal threats, for example, from patent trolls. However, the US Supreme Court has started to limit patentable subject matter and rein in patent assertion activity, which may mitigate the costs of operating in thicket-dense areas. For example, the Court in *eBay v. MercExchange* (2006) has ended automatic injunctions (of the sort faced by RIM), which can put enormous pressure on alleged infringers.[30] Complementing this have been patent reforms such as the *America Invents Act* (2012), which allows third parties to petition (or challenge) claims of granted patents, as long as they can demonstrate "reasonable likelihood that [they] would prevail with respect to at least 1 of the claims challenged in the petition."[31]

The Supreme Court decisions bode well for patent owners in that they constrain patent trolls from making bogus claims. This is particularly relevant to Canada, given the recent analysis by Torrance and West (2017) commissioned by the Canadian government.[32] Based on the comprehensive data set of decades of US patent and related data, they find that USPTO-granted patents that are either owned or developed with at least one Canadian inventor are on average approximately 15 percent more valuable than other patents, where value is assessed in terms of patent and nonpatent citations. In contrast, adding another "generic" non-Canadian inventor tends to lower the average patent value. Although the reasons for these results are not identified, the evidence of Canadian value-added to US patents is compelling, thereby strengthening the case for supporting Canadian ownership of them.[33]

Overall, the evidence reviewed provides solid support for the view that *patent ownership* is vital to small firms trying to move to later stages of commercial exploitation. It is also the case, however, that some Canadian innovators, facing search, negotiation and uncertain legal costs of moving to the next stage of the innovation process, may simply conclude that selling their IP assets to larger patent owners would be more profitable.[34] We turn now to data on patent ownership in Canada.

---

[30] *eBay v. MercExchange*, 547 U.S. 388 (2006). See Mezzanotti (2015) for a discussion of this decision and the impact on trolling behaviour resulting from it.

[31] For more information, see H.R. 1249 — 112th Congress (2011-2012), https://www.congress.gov/bill/112th-congress/house-bill/1249.

[32] See KU News Service (2016) and Torrance and West (2017).

[33] For example, the results may be attributed to Canadian inventors self-selecting into technology areas of their expertise more effectively than researchers in other countries, high-quality STEM education in Canada or different funding opportunities in Canada. Of course, lower-quality patents (not meeting the patent standards) would still be subject to potential challenges by third parties.

[34] See Galasso, Schankerman and Serrano (2013) for an empirical analysis of the impact of IP reassignments on the incidence of patent litigation in the US. The extent to which Canadian patent owners have been the target of legal disputes in the US would be interesting to identify, although it would not capture those innovators who opt to sell and abandon R&D rather than incur the costs of legal suits.

CANADA IN GLOBAL MARKETS: EMPIRICAL EVIDENCE ON OWNERSHIP

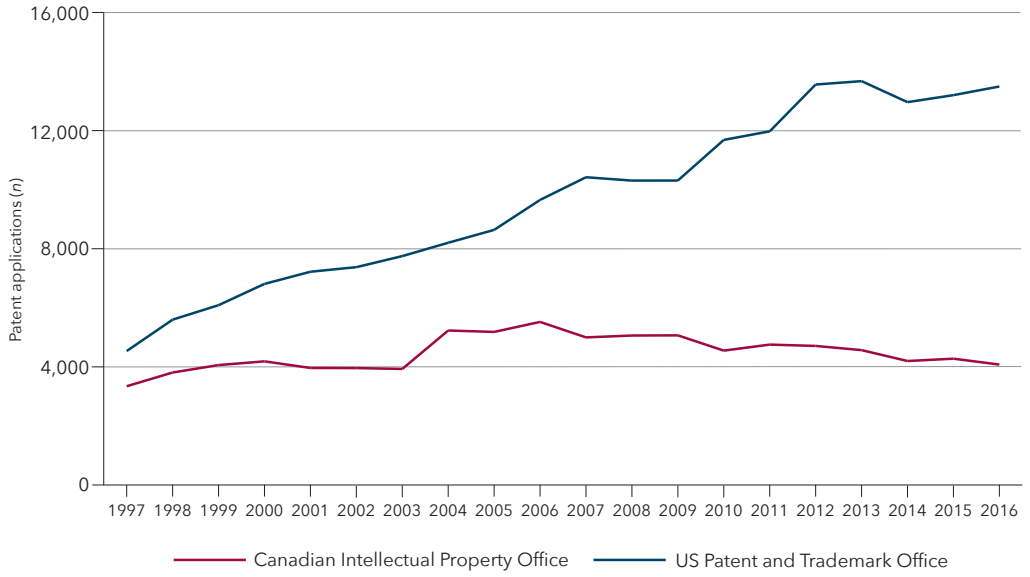
If Canadian businesses are to compete in the global marketplace, they require not only the ability to discover new products and processes but also the associated IP rights to carry them to scale. In this sense, we argue, IP ownership is among important factors that contribute to "scale-up potential." Indeed, this is consistent with the view that patents are "a solid measure of a country's capacity to innovate, since filing one is the first step toward commercializing new technologies" (McKenna and Torobin, 2010).

In this section we examine the extent to which Canadian inventors own their patents and in which technological areas. Due to data limitations, we restrict our attention to patents filed and granted in the US (by the USPTO) that involve Canadian inventors and those in peer countries. As our interest is in inventors seeking international markets, a focus on patents granted in the US – the largest international market – provides a good approximation of Canadian inventors' global reach.

Patent activity by Canadian residents in Canada and the US

Because Canada is a small market providing limited opportunities to achieve economies of scale and profitability in most high-technology industries, many Canadian innovators seek patents in the US. In fact, Canadian inventors apply for and are granted patents in the US far more frequently than in Canada. Figures 6 to 8 illustrate relative patent activity by Canadian residents in Canada and the US.

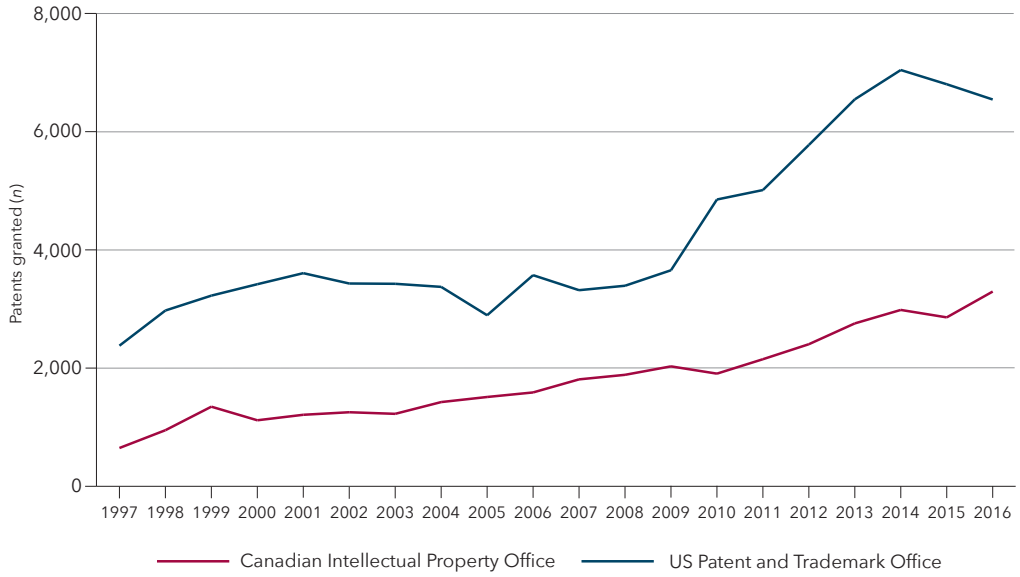
Figure 6. Patent applications in Canada and the US by Canadian residents,[1] 1997-2016



Source: World Intellectual Property Organization, "WIPO IP Statistics Data Center," https://www3.wipo.int/ipstats/index.htm?tab=patent.

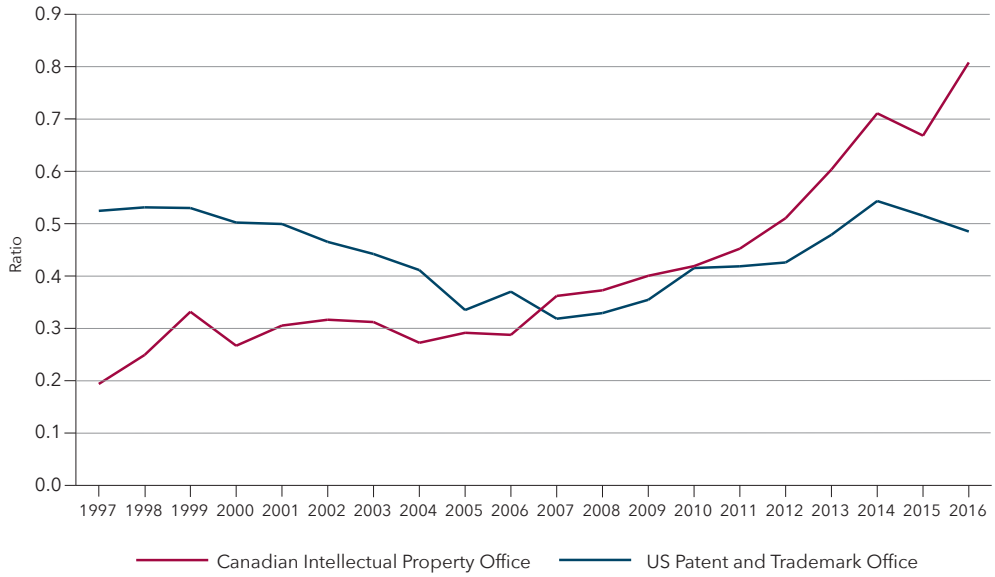
[1] Patent applications filed in Canada and the US for which Canada is the country of origin. The country of origin is Canada if the first-named applicant resides in Canada. See the World Intellectual Property Organization's definition of "origin" (World Intellectual Property Organization n.d.).

Figure 7. Patents granted in Canada and the US to Canadian residents,[1] 1997-2016



Source: World Intellectual Property Organization, WIPO IP Statistics Data Center, https://www3.wipo.int/ipstats/index.htm?tab=patent.
[1] Patents granted in Canada and the US for which Canada is the country of origin. The country of origin is Canada if the first-named applicant resides in Canada. See the World Intellectual Property Organization's definition of "origin" (World Intellectual Property Organization n.d.).

Figure 8. Patent grants-to-applications ratio, Canadian residents, 1997-2016[1]



Source: World Intellectual Property Organization, WIPO IP Statistics Data Center, https://www3.wipo.int/ipstats/index.htm?tab=patent.
[1] Patent applications and grants filed in Canada and the US for which Canada is the country of origin. The country of origin is Canada if the first-named applicant resides in Canada. See the World Intellectual Property Organization's definition of "origin" (World Intellectual Property Organization n.d.).

As shown in figure 6, in 2016 the number of patent applications filed by Canadian residents in the US was nearly three times that in Canada. Note that patent applications

filed by Canadian residents in Canada have been stable over time with a slight decline in recent years. However, they have risen substantially in the US, suggesting declining emphasis by Canadian inventors on securing IP in Canada relative to the US (and more broadly, the global market). On the other hand, patents *granted* to Canadian residents have been on the rise in both jurisdictions; by 2016, the ratio of Canadian-invented patents granted in the US relative to Canada was approximately 2:1 (figure 7).

Together, the data in figures 6 and 7 indicate the rate at which Canadians were successful at securing patents in Canada and the US. As figure 8 reveals, Canadian residents were more likely to be granted patents on their applications in the US before 2007. However, more recently, the success rate of applications to the Canadian Intellectual Property Office (CIPO) has overtaken that of applications to the USPTO, which has remained relatively steady.

These trends imply that in the mid-1990s and early 2000s, Canadian residents were more likely to be successful in their patent applications in the US than in Canada. One explanation for the relatively low success rate in Canada may be that inventions in applications filed in Canada only were on average of lower quality. In an empirical analysis of Canadian inventors' decisions to patent in Canada, the US or both countries, Eckert, Langinier and Zhao (2018) provide evidence that higher-quality inventions tended to be filed in both countries, and not in the US only. Understanding the factors that affect firms' patenting locations is an important topic for further research, as Canadian-invented patents granted by the USPTO are among the most promising candidates for scaling up in Canada and achieving global commercialization.

What may be of greater significance in today's competitive environment is the fact that Canadian-sourced patent applications – which have been on the rise in the US – have been able to hold their ground in securing US patent grants. At first glance, this would seem to bode well for Canada's future innovative outlook. However, a closer look at these patent grants reveals a striking and potentially concerning feature: many USPTO patents granted to Canadian inventors are assigned immediately to foreign entities at the date of issue. That is, while Canadian residents may have been involved in the invention process, many do not become owners of the patents. This has important implications for Canada's capacity to scale up, research, develop and commercialize promising new products that depend on essential IP.

Canadian-invented patents granted by the USPTO

The USPTO database is particularly useful for examining patent assignment and ownership in large global markets because it provides the name of inventor(s), name of assignee(s) and countries of residence for both. Therefore, the data track patent assignments on the day that patents are granted for Canadian-invented patents, as well as patents invented by residents of Canada's comparator countries.[35]

[35] As noted, Eckert, Langinier and Zhao (2018) provide an empirical analysis of Canadian inventors' decisions on where to patent: Canada only, US only or both. In contrast to their research, we do not examine the locational decision but rather consider the assignment of Canadian-invented patents, conditional on patenting in the US.

Given our interest in analyzing the assignment activity of Canadian-invented patents, it is important to note that multiple inventors are named on many of the patents granted. Using the USPTO database, we identify a USPTO patent as originating from country X if *at least one inventor resides there*.[36] Therefore, to identify Canadian-invented patents, we collect all patents issued in the US in which at least one inventor is a Canadian resident, including foreign subsidiaries registered in Canada. Although multiple foreign inventors also may be named on the patent, this nevertheless is a useful measure of innovative capacity in Canada as it identifies those patented inventions that benefited from Canadian input.

If the Canadian inventor or members of their team are employees of a foreign firm or engaged in a research contract with a foreign firm (for example, a public-private partnership involving university researchers), the patent grant will most likely be *assigned* to that firm on the date the patent is issued. That is, the firm becomes the *owner* of the patent right. Although the nature of the relationship between the inventor and owner (*assignee*) would require further inquiry, a cursory check of a random sample of the assignees, crossed with LinkedIn data on the assignors, indicates that several of the inventors are employed by the foreign entity. It would be interesting to explore this issue more systematically in future research.

To get additional insight into the propensity to assign, we examine a random sample of 200 patents attributed to Canadian inventors in each of 2007, 2012 and 2017 to test the hypothesis that the greater the Canadian presence on the research team, the more likely it is that patents are assigned (that is, ownership is transferred) to a Canadian resident. (This sample includes only patents that had at least one Canadian inventor listed.) A simple probability model, in which Canadian assignee (0-1 variable) is regressed on the proportion of Canadian inventors listed on the patent out of all inventors, generates significant positive coefficients in each of the three years.[37] That is, assignment (ownership) to a Canadian resident is strongly correlated with the proportion of Canadians on the research team; and, for this sample, the marginal impact of Canadian presence on the team increased over time. Although these positive results should be viewed with caution, given the small sample, they highlight the value of conducting a comprehensive study on the implications for innovation in Canada of Canadian researchers' participation on international teams (see, for example, Torrance and West 2017).

In general, many Canadian-*invented* patents do not result in Canadian-*owned* patents. In fact, the 2017 data reveal the stark result that the majority of "Canadian-invented"

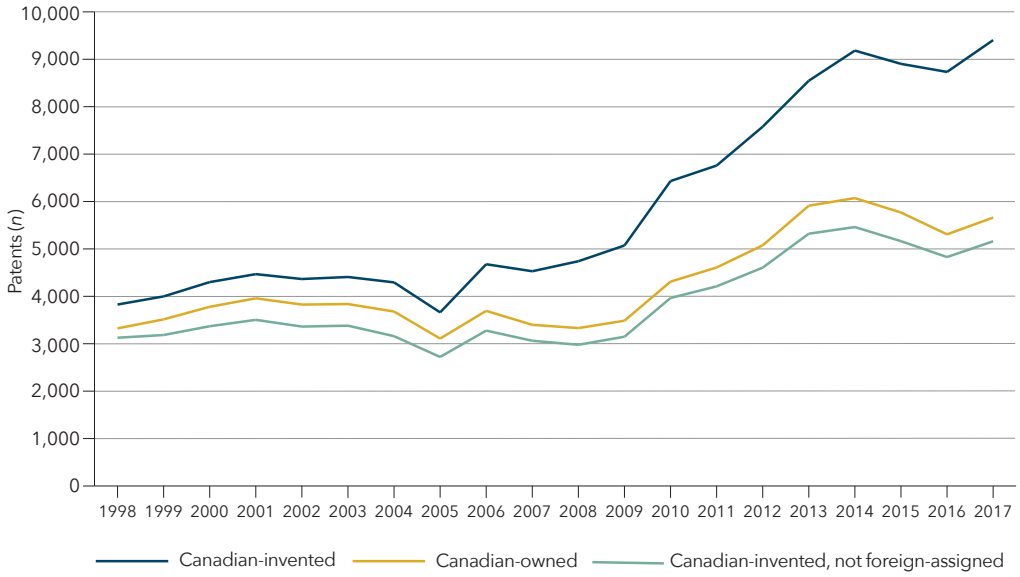
[36] The USPTO database used is the Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm. Our approach in this section is consistent with the methodology used in Plant (2017). However, for the World Intellectual Property Organization (WIPO) data used in figures 6 to 8, the "country of origin" is Canada if the first-named applicant resides in Canada. Typically, this is the assignee, who may or may not be the inventor.

[37] The respective coefficients and standard errors (in parentheses) are 0.525 (0.134), 0.665 (0.116), 0.723 (0.116). Thus, for example, in 2005, if the proportion of Canadian inventors increased from, say, 1/3 to 1/2, the implied probability of assignment to a Canadian resident increases by the difference (1/6) times 0.525, or by 8.7 percent. The results suggest that the impact of Canadians on research teams increased over the past decade. Closer examination of the underlying data reveals that the increase was attributable primarily to teams with more than 70 percent Canadians. In those cases, the percentage of patents assigned to Canadians increased from 58 percent to 64 percent between 2007 and 2017. For smaller teams, the percentage of patents staying in Canada fell from 26 percent to 21 percent.

patents issued in the US are assigned to firms outside Canada or foreign subsidiaries in Canada on the date of issue.[38] This outcome is attenuated by the fact that patent assignments also flow into Canada from foreign inventors.

Figure 9 plots the time series of the Canadian-invented US patents. The highest curve shows the number of patents issued in the US in which at least one Canadian was listed as an inventor. Note that patenting activity has doubled over the last 20 years. The lowest curve represents the USPTO patent grants, both invented by and assigned to Canadian residents after subtracting patent grant assignments to foreign firms.[39] Among those patents awarded to Canadian residents are patents granted to foreign subsidiaries with a Canadian address.[40] Finally, the intermediate curve represents *net patent ownership* in Canada of US patents: Canadian-invented patents *minus* those assigned (on the date of issue) to entities with a non-Canadian address *plus* patents without a Canadian inventor assigned to a Canadian resident.[41] Canada thus has a

Figure 9. US patents: IP invented and owned by Canadians, 1998-2017



Source: US Patent and Trademark Office, USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm.

[38] For simplicity, the term "Canadian-invented patents" is used to refer to patents issued in the US for which at least one Canadian resident is named as an inventor. Consistent with the observations here, Plant (2017) finds that 55 percent of patents "made in Canada" were assigned to another country, while Canada did not fare well as an assignee of patents from other countries. In our analysis, we combine the patent outflows and inflows to find Canadian net ownership: Canadian-invented patents minus assignments from Canada to a foreign firm plus assignments from foreign inventors to Canadian firms. This is similar to analysis conducted by the CCA (2018).

[39] For the data set considered here, only patent assignments that occur on the date of the patent grant are identified.

[40] Data provided by Plant (2017) show that in 2015 foreign subsidiaries received nearly 37 percent of patents attributed to the top 100 R&D companies in Canada. Furthermore, these data reveal that 15 percent of foreign subsidiary patents are assigned to Canadian firms. Therefore, the remaining 85 percent could have been assigned to the foreign parent or other foreign entity, or retained by the foreign subsidiary in Canada.

[41] As patents assigned to Canadian residents are not directly available, the data series was constructed using a subsample of the 25 countries that had the largest number of patents issued in the US. The number of assignments from countries outside this subsample is likely to be immaterial, given that the top 25 countries represent over 98 percent of total patents granted by the United States Patent and Trademark Office in 2015 (United States Patent and Trademark Office n.d.).

"patent assignment deficit" – defined by the number of foreign-invented patents assigned to Canadian firms minus the number of Canadian-invented patents assigned to foreign firms. This patent deficit, illustrated by the gap between the middle and top curves, grew by over seven times from 1998 to 2017.[42]

To sum up, net patent ownership in Canada is significantly less than patents invented (more precisely, invented with Canadian input), and the gap is growing over time. Over the past two decades, the number of Canadian-invented patents that were never assigned (i.e., that stayed with the original inventor) fell from 32 percent to 13 percent. That is, patents that have at least one Canadian inventor are increasingly being assigned to domestic or foreign firms. Over that same period, the percentage of patents assigned to foreign entities more than doubled, from 18 percent to 45 percent. While understanding this trend would require a deeper analysis of the data, economic forces and changes in government policy at play, we note that this increase in assignments to foreign entities may reflect, in part, an increase in innovation activities by foreign subsidiaries in Canada (that assigned their patents to foreign parents) or in participation by Canadian residents in international research teams controlled by foreign firms, or both.[43]

The data we are using have three weaknesses. First, we may be underestimating Canadian-owned patents in that foreign assignees of Canadian-invented patents could be Canadian subsidiaries located in foreign countries. (We were unable to capture ultimate ownership of all companies listed as assignees.) Second, we may be overestimating Canadian ownership by including all patents assigned to Canadian residents, some of which could be US subsidiaries that ultimately reassign their patents to their foreign parent. Third, since the identification of Canadian-invented patents includes all those with at least one Canadian resident listed among the inventors, disproportionate credit may be given to Canadian inventors with a relatively minor contribution.

Comparison with other OECD countries

An important feature of the Canadian innovation landscape is that most USPTO-granted patents attributed to at least one Canadian inventor are actually owned by foreign entities and foreign subsidiaries in Canada. In this section, we examine whether this pattern is also found in peer OECD countries.

[42] In particular, Canadian-invented patents assigned to foreign firms in 1998 and 2017 were 700 and 4,243, respectively, and foreign-invented patents assigned to Canadian residents in those years were 197 and 500 respectively.

[43] Understanding why so many patents with Canadian input are assigned to foreign firms would be useful for policy, but this would require a much larger discussion around the state of the Canadian economy, the degree to which assets (not simply IP) in Canada are foreign-owned, employment of PhDs in the US versus Canada, trade policies, etc. Also, it would be interesting for future research to compare the average quality of inventions assigned to foreign entities and those remaining in Canada, where quality would be measured by citations or triadic patents (inventions/patents in multiple jurisdictions). As noted above, Eckert, Langinier and Zhao (2018) examine empirically the quality of inventions filed for patents in Canada versus the US. The exercise we are proposing for future research would focus instead on the subset of Canadian-invented patents issued by the USPTO that are retained in Canada versus those assigned to foreign entities.

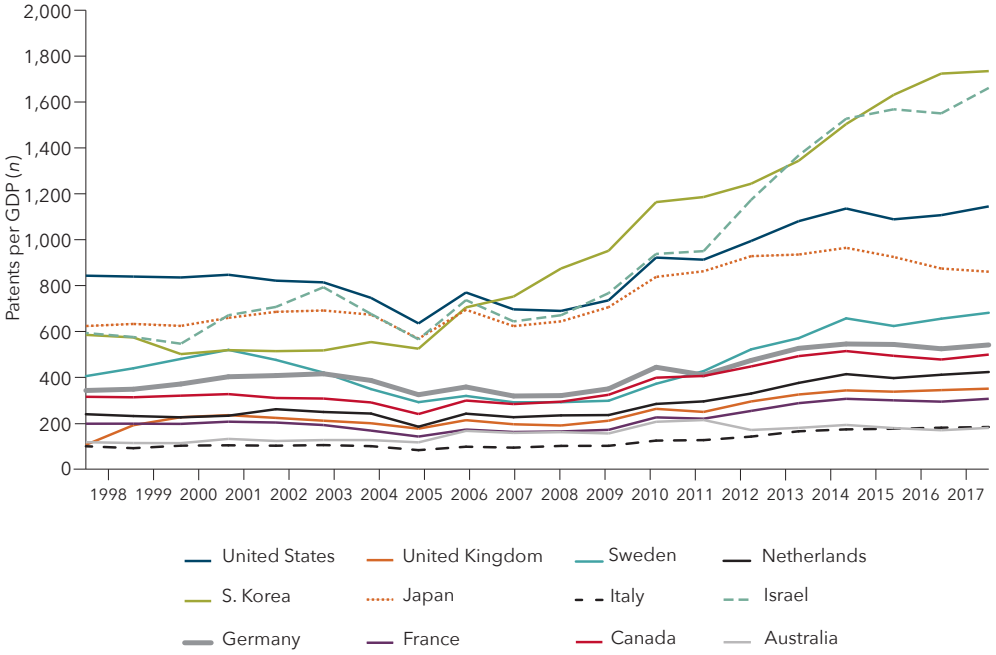
We begin by identifying peer OECD countries that have similar-sized open economies. The US, where the patents are issued, is also included for comparison. Our selection process depends on two variables: per capita GDP and population. Of the 12 countries in the sample, Israel is the smallest according to population and the US is the largest. The US also has the highest per capita GDP and Israel the lowest.

In order of innovative activity (patents) relative to their GDPs, the countries are:

- South Korea, Israel, Japan and the US
- Sweden, Germany and Canada
- the Netherlands, the UK, France, Australia and Italy

Canada is approximately in the middle of the pack in terms of patents per GDP.[44] This is shown in figure 10, which plots the time series of USPTO patents attributed to inventors from peer countries.[45] The time series is interesting in that it shows that some countries with relatively low patent productivity in earlier years become "patent

Figure 10. US patents granted, selected countries, 1998-2017[1] (per $100 billion GDP)



Sources: US Patent and Trademark Office, USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm; World Bank national accounts data and OECD National Accounts data files, "GDP (constant 2010 US$)," https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?.
[1] Patent origin is shown as the selected country if at least one inventor resides in that country.

[44] GDP is measured in figures 10 through 15 in constant US dollars, using market exchange rates.
[45] When R&D is weighted according to comparative advantage for countries (for example, natural resources in Canada), Canada does much better among OECD countries (CCA 2018). A similar exercise could be conducted for patents. For example, the oil sands industry is R&D-active but patents are relatively less common. Rather, industry players tend to share knowledge as in Canada's Oil Sands Innovation Alliance (www.cosia.ca), which facilitates research collaboration to address shared challenges.

tigers" – high patent-producing countries, as referred to by Barnett (2017) – when they alter their innovation strategies.[46]

We also compare the countries according to patent ownership. As noted earlier, a significant proportion of Canadian-invented patents are assigned to foreign firms when the patent is granted; that is, the Canadian inventor is not the patent owner or patentee. Consequently, if the Canadian researcher wishes to engage in further research involving that invention, for example, to improve upon for commercialization purposes, they would need to pay the patent owner for a licence or risk being sued for infringement. We want to examine whether high rates of foreign assignment of USPTO patents are also found in other OECD countries. To put it differently, how does Canada compare with peer countries in terms of *scale-up potential* as indicated by patent ownership? We contrast this ranking in scale-up potential with Canada's *inventive capacity* – patents invented by Canadian residents – relative to its peer countries.

Constructing the data in the same way as we did in figure 9, we compare Canada with peer OECD countries in terms of patent ownership per GDP: patents granted in the US filed by inventor in country X net of those assigned to foreign firms, plus foreign-invented patents assigned to country-X firms. Data sets of cumulative patents invented by country X and net ownership for the 2013-17 period are constructed and shown in figure 11. The grey and blue bars indicate, respectively, patents invented in country X and patents owned in country X. The bars are in descending order of invention. Note that Canada moves from seventh place in inventive activity to eighth place in IP ownership.

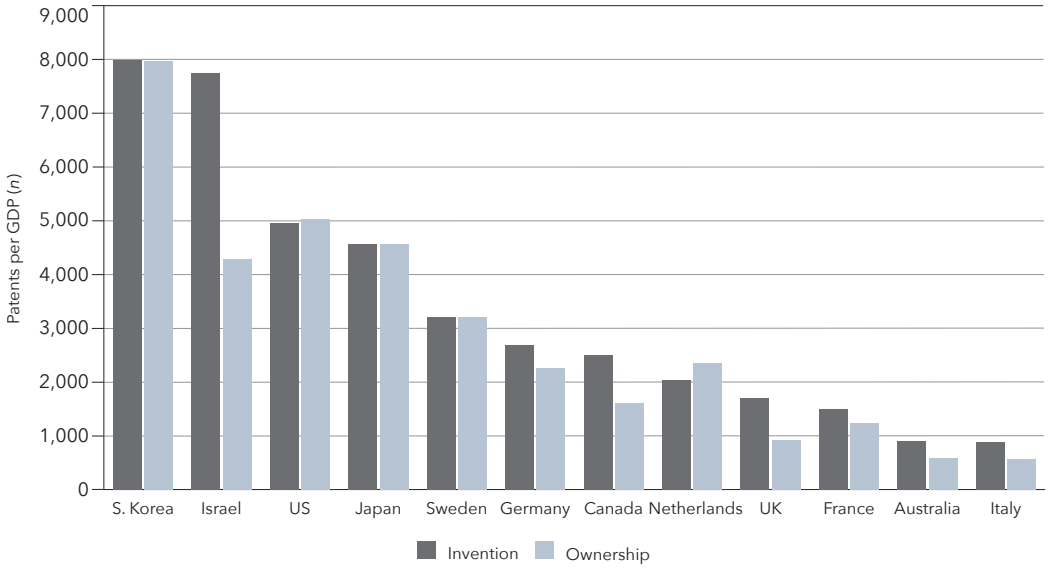
Although Canada falls only marginally in the ranking from "invention" to "ownership," these data nevertheless confirm that a relatively large proportion of Canadian-invented patents are assigned outside of Canada. In this respect, Canada is similar to other countries ranked in the lower half of the distribution.[47]

Although this may seem alarming at first glance, it also indicates that foreign corporations value Canadian innovative human capital, and have invested in Canada to take advantage of this talent. The upside is that these investments can benefit Canada to the extent that Canadian researchers working for foreign subsidiaries acquire technological and managerial expertise that might otherwise be unavailable.

[46] Barnett's (2017) selection criterion focuses on countries with patent intensity greater than some threshold. We do not adopt his patent-based selection, as that is what we seek to explain. Nevertheless, as our economic measure (per capita GDP) is correlated with patent activity, our set of countries is similar to that in Barnett. We do not include Austria because of its relatively small population, or Switzerland because of its relatively high GDP. Moreover, the last group of countries (relatively low patent performers) is not included in Barnett's sample. Finally, we expect that US inventors will be overrepresented in the USPTO data relative to foreign inventors, which can be attributed to domestic preference in patenting.

[47] The outlier is Israel, which, like Canada, has a high proportion of its invented patents that are foreign-assigned but, unlike Canada, ranks high in terms of both inventiveness and ownership per capita.

Figure 11. US patents: IP invention and ownership, selected countries, 2013-17 (per $100 billion GDP)



Sources: US Patent and Trademark Office, USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm; World Bank national accounts data and OECD National Accounts data files, "GDP (constant 2010 US$)," https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?.

The downside, of course, is that ownership of the IP may not stay in Canada, in which case barriers to further development would be greater. In particular, Canadian innovators would need to license inventions assigned to foreign corporations on the date of patent issue if they wished to advance to the next stages of commercial exploitation. More likely, it will be the foreign corporation that will develop, commercialize and obtain the resulting benefits.

The case of Israel illustrates this distinction between patents invented and patents owned. While Israel, like Canada, assigns a large proportion of its patents to foreign entities, it starts with a much larger base of patents attributed to Israeli inventors relative to its GDP. That is, Israeli researchers appear to be more actively involved in global research, relative to Canada. Israel's relatively high assignment flow nevertheless leaves it with very strong scale-up potential, making it one of the patent tigers (Barnett 2017) among small open economies.

A closer examination of the Israeli case – its industrial structure and innovation strategies – may provide useful lessons for Canada. Breznitz and Ornston (2014) argue that an important part of Israeli innovation success can be attributed to the work of its innovation development agency (the Office of the Chief Scientist). Since the agency operated on the periphery of the public sector, it was not limited to doing the same activities and supporting the same industries as in the past. However, Breznitz and Ornston also note that the Office of the Chief Scientist had "an unlimited annual budget for its main R&D fund, so that all approved projects to develop high-technology products suggested by private industry would be supported" (265).

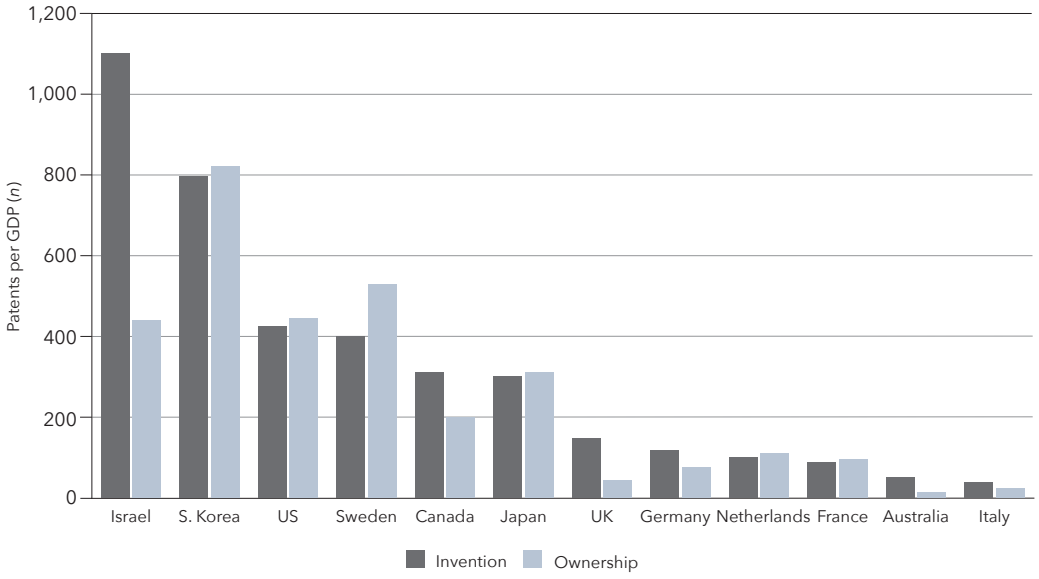
Technology fields

The CCA (2018) report identifies computer technology, telecommunications and aerospace as areas of technological strength for Canada, based on a composite index of the average annual R&D expenditures, R&D as a share of revenues and the compound annual growth rate. It is interesting to look at where Canada ranks in terms of patented products and processes in these areas, as well as in pharmaceuticals (reported as an area of technological strength in the 2013 CCA report) and artificial intelligence (AI). Following the same methodology as above, we examine Canada's ranking among peer OECD countries in terms of patents invented and owned by Canadian residents in each area.

Information and communication technologies (ICT)

Figure 12 shows the ranking of OECD countries in ICT (specifically, computers and telecommunications). Note that Canada ranks in fifth place in invention among comparator countries but drops behind Japan to sixth place in ownership, securing only two-thirds of Japan's capacity relative to GDP, half of Israel's and a quarter of South Korea's capacity. Approximately 43 percent of Canadian-invented telecommunications patents and 48 percent of computer patents are assigned to foreign owners at the date of issue. Thus, the pattern in this sector is consistent with the general patent picture shown in figure 11.

Figure 12. US patents: IP invention and ownership in information and communications technologies, selected countries, 2013-17 (per $100 billion GDP)

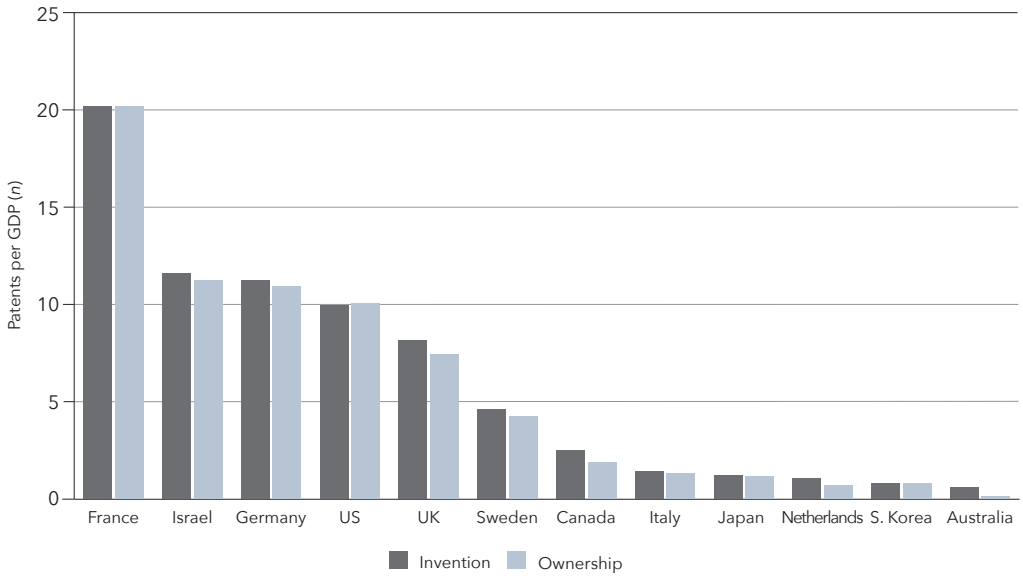


Sources: Calculations by the authors based on US Patent and Trademark Office, USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm; World Bank national accounts data and OECD National Accounts data files, "GDP (constant 2010 US$)," https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?.

Aerospace

The results for aerospace are similar to those for ICT. However, as figure 13 shows, both the number of patents attributed to Canadian inventors and the number owned by Canadian residents are significantly lower than those in peer countries ranked in the top half of the distribution. This places Canada in the lower half of the distribution in terms of scale-up potential.

Figure 13. US patents: IP invention and ownership in aerospace, selected countries, 2013-17 (per $100 billion GDP)



Sources: Calculations by the authors based on US Patent and Trademark Office, USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm; World Bank national accounts data and OECD National Accounts data files, "GDP (constant 2010 US$)," https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?.

Pharmaceuticals

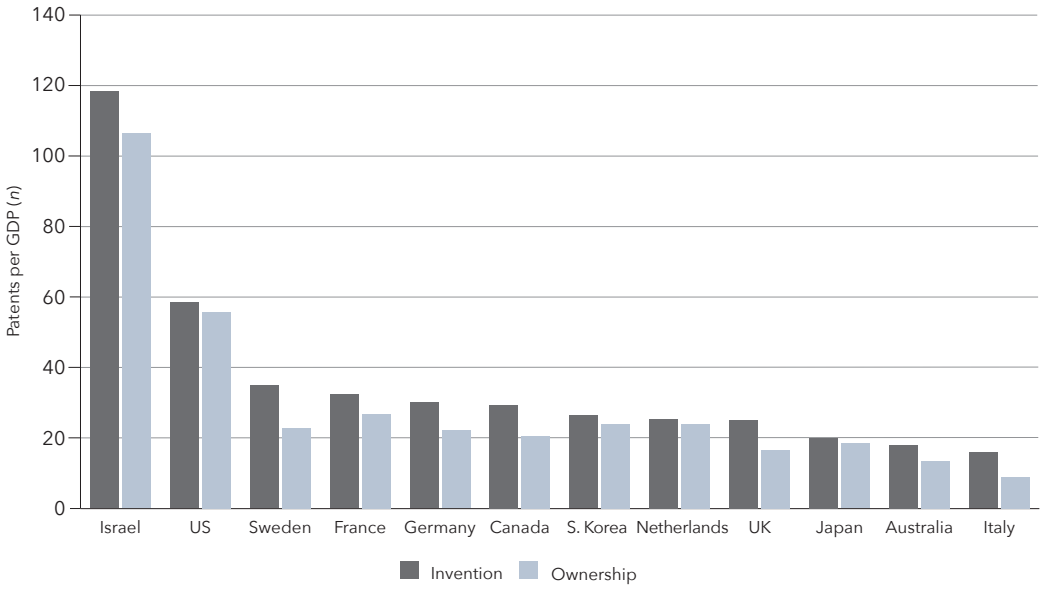
In the pharmaceutical sector, Canada ranks sixth in inventiveness but falls to eighth place in ownership (see figure 14). Unlike in ICT and aerospace, however, Canada's performance in both categories is closer, in terms of patents per GDP, to that of other countries in the sample, except for Israel and the US.

Artificial intelligence

Many observers view AI as a promising sector of innovation activity for Canada. The CCA report (2018, xxii) notes that Canadian researchers engaged in pioneering research in artificial intelligence and regenerative medicine "retain a substantial research capacity" but have "lost ground to other countries." This is reflected in Canada's relative standing in patent ownership, in contrast to its contributions as a research pioneer.

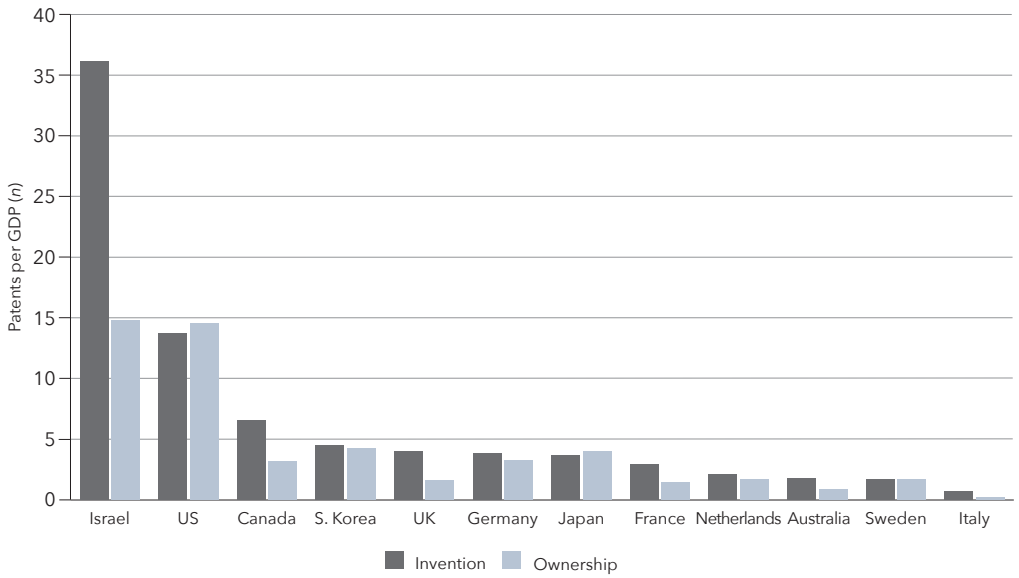
Among the peer group shown in figure 15, Canada was the third most active country in AI, as measured by USPTO-granted patents that included at least one Canadian inventor during the 2013-17 period. However, only 7 percent of those patents remained with Canadian inventors on the date of issue. This free fall from invention to ownership

Figure 14. US patents: IP invention and ownership in pharmaceuticals, selected countries, 2013-17 (per $100 billion GDP)



Sources: Calculations by the authors based on US Patent and Trademark Office, USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm; World Bank national accounts data and OECD National Accounts data files, "GDP (constant 2010 US$)," https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?.

Figure 15. US patents: IP invention and ownership in artificial intelligence, selected countries, 2013-17 (per $100 billion GDP)



Sources: Calculations by the authors based on US Patent and Trademark Office, USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm; World Bank national accounts data and OECD National Accounts data files, "GDP (constant 2010 US$)," https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?.

was tempered by domestic assignments (40 percent), which helped maintain Canada in sixth place in patent ownership. As Hinton and Cowan (2017) note, almost all investment in Canada in the machine learning field has been for and by foreign-owned multinational companies.[48] In effect, Canadian researchers have been active in this technology space, but have lost capacity in terms of IP ownership for scaling up and moving on to the subsequent stages of commercial exploitation.

What happens to the patents retained by Canadian owners?

Our analysis of USPTO data on patents owned by Canadian residents (as opposed to invented by Canadian researchers) indicates that Canada typically falls in the bottom half of the distribution among peer countries, even in areas where it is considered to have a comparative advantage. We interpret the extent of ownership as an indicator of scale-up potential since it represents the invention base from which Canadians can develop and commercialize marketable applications without facing licensing royalties or potential costs of infringement.

We also want to know what happens to patents that remain in Canada. In particular, what proportion of those patents is eventually sold to foreign entities before reaching the commercialization and sustainability stages in the innovation process? To approximate the extent to which patents are later reassigned, we construct a new data series based on a random sample of 200 US patents drawn from Canadian-invented and -assigned patents granted in 2007, and track any reassignments of them over the following 10 years. We also record whether the patents were reassigned to a foreign or Canadian resident.

This exercise, although based on a small sample, provides interesting insights regarding the transfer of ownership of USPTO-granted patents held by Canadian residents. We find that of patents issued in 2007 that were invented by and assigned to Canadian residents at that time, 47 percent were subsequently reassigned over the next decade. Of these, 44 percent were reassigned to foreign firms and 56 percent to Canadian residents. Therefore, of the sample of 200 Canadian-owned patents in 2007, 21 percent were later reassigned to foreign firms and 26 percent to Canadian residents while 53 percent remained with the first assignee. We caution, however, that the sample does not include unassigned patents (that is, those retained by the Canadian inventor when issued in 2007) or account for foreign patents reassigned to Canadian firms.[49] Nevertheless, these subsequent reassignments represent a potential worsening of the patent assignment deficit discussed above. They also point to an important area for further research: to track reassignments of Canadian-owned IP, by whom and to whom, in which technology areas and at what stage of development in the innovation process.

[48] Patent reassignments attributed to Canadian inventors working for a foreign subsidiary or in a team of employees of a foreign firm reflect both the supply of and demand for Canada's talent.

[49] In 2017 around 13 percent of total patents were attributed to at least one Canadian inventor and not assigned at the time of patent grant.

The supply and demand of Canadian IP

We have already discussed some of the reasons why SMEs may decide to sell (or reassign) their IP rather than engage further in the R&D process; for example, if they expect high costs of royalties, or litigation, particularly from large firms owning patents essential to further development of their technology.

Correspondingly, those (or related) large firms may find Canadian-owned IP attractive to buy. This may be true especially for vertically integrated firms in the US with resources to hire international teams of researchers. These firms may find that licensing Canadian IP is less profitable than purchasing the IP, or even the entire firm with its other assets and technical staff.

The literature provides evidence that cross-border mergers are more likely when the firms share a common language and other cultural similarities (Ahern, Daminelli and Fracassi 2015; Buch and DeLong 2004).[50] The costs of acquiring information are likely to be lower for Canadian inventions. Moreover, given Canada's relatively flexible immigration policies, the diversity of the research team may be most profitably retained by keeping the team in Canada, especially for skill-specific technology. Therefore, all else being constant, Canadian firms with valuable IP may be particularly attractive to US companies for cross-border mergers, relative to firms in other countries. This would be consistent with the CCA's argument (2018) that Canadian inventors develop inventions that are valuable to US firms because of Canada's dependence on US foreign direct investment and trade.[51]

Structural factors affecting scale-up: The rise of "superstar" firms

While we highlight the importance of Canadian ownership of IP in gauging Canada's commercialization potential in highly competitive global markets, we recognize that it is only one factor to be considered. The ability of Canadian firms to advance to subsequent stages of commercial exploitation also depends on their ability to compete, not only in research but also in commercialization of the final product.

One structural feature of global markets that is particularly relevant to Canadian firms contemplating scaling up is the growing dominance of large, vertically integrated network enterprises.

---

[50] A merger could also involve acquisition of a US company by a Canadian one. Data from 2016, in fact, reveal that mergers between Canada and the US – measured by numbers and value of transactions – are predominantly from Canadian purchases of US assets rather than the other way around (Wright 2016). The data are not sufficiently detailed to determine if the acquisitions are in innovative, knowledge-based industries.

[51] As the CCA noted (2018,156), Nicholson suggests that Canada's close foreign direct investment and trade relationship with the US may have directed US subsidiaries and exporters in Canada to focus on "incremental, operational improvements (i.e., plant-floor innovation) rather than the development or adoption of more novel goods, processes, or technologies," or on producing "intermediate goods or services provided as part of integrated, continental value chains." This contrasts with countries that have access to diverse markets for their final goods (for example, South Korea and Switzerland). However, it does not explain why Canadian firms, unlike Israeli firms, have not been able to monetize upstream investments by scaling up intermediate input operations (Barnett 2017).

Indeed, the increasing industrial concentration in the US, Canada's most important trading partner, is an important factor affecting Canadian firms' ability to grow. Autor et al. (2017) document the rise of "superstar" firms that dominate the industries in which they operate, undermining opportunities for competitors through their position. Canadian technology firms have not become superstars in the same way; they are instead operating at much smaller scales.

Table 1 shows the largest Canadian technology-intensive firms listed on the Toronto Stock Exchange and the largest US firms in matching industries. The leading US superstar companies have a market valuation that is roughly two orders of magnitude greater than the leading Canadian companies in their sector. The scale of the US firms enables a greater degree of integration in three dimensions: across countries, horizontally with respect to substitute products, and vertically with respect to inputs. Consequently, these companies have been able to transform themselves effectively to achieve sustained innovation, which has become their business model, in contrast to the leading Canadian companies.

Table 1. Largest Canadian and US technology-intensive firms, 2018

Industry	Canadian leader	Market cap (C$bn)	US leader	Market cap (C$bn)
Internet sales and advertising	Shopify	21	Alphabet	978
ICT hardware and software	BlackBerry	6	Apple	1,079
Pharmaceuticals	Bausch Health (Valeant)	11	Johnson & Johnson	522
Aerospace	Bombardier	5	Boeing	247

Source: Research by the authors based on Google Finance, December 11, 2018, https://www.google.com/finance.

Hence, it is not simply the threat of litigation that may affect SMEs' sell-versus-scale-up decision. It is also their inability to compete with these large firms upon commercialization of their new product. Large companies are able to exert a degree of market power in specific markets that can support significant investment in innovation, which is difficult to replicate for smaller companies. In addition, such companies may effectively suppress competition from smaller firms because of "network effects." In industries characterized by network effects, once everyone else is using a company's product, it becomes particularly difficult for competitors to break into the market because of interoperability concerns. If large companies are able to capture a disproportionate share of rents available in each industry, small companies will not be able to develop the financial capacity to support sustained investment in innovation to achieve comparable scale.

In fact, knowledge-based firms in the US (and globally) are becoming increasingly vertically integrated. In the recent mergers of AT&T and Time Warner, Comcast and NBC, CVS and Aetna, firms have combined their complementary assets to compete more effectively in a global market occupied by other vertically integrated giants such as Amazon and Netflix. Vertical integration can, in some circumstances, increase the market power of the integrated firms.

To the extent that superstar companies dominate global markets, Canadian policy response options are limited. It is difficult to develop home-brewed innovation superstars, although RIM came close, and it seems unlikely that the government has the ability to identify such firms in any case. China has effectively created its own superstar companies, such as Alibaba and Baidu, by blocking access to its domestic market to many leading US firms, but this solution is not available to Canada. A more aggressive competition policy may be helpful but is unlikely to be driven by concerns about increasing innovation ownership in Canada.

Changes in Canada's innovation policies are not likely to alter these inherent structural differences. This would require a carefully designed industrial policy, which is beyond the scope of this study. We argue, however, that innovation policy should include measures to facilitate Canadian involvement in international collaborations that support fundamental research in Canada. This is consistent with the message from the Advisory Panel for the Review of Federal Support for Fundamental Science (2017), and with the data presented in this section, which suggest that supporting more Canadian-led research teams may facilitate greater IP ownership. Canadian innovation policies can also have a significant impact on incentives to retain IP ownership in Canada.

POLICY IMPLICATIONS AND RECOMMENDATIONS

Recent policy discussions in Canada indicate that policy-makers are acutely aware of the challenges of operating in complex and litigious global markets and the importance of IP ownership. In this section, we discuss both patent and nonpatent policy options for improving the creation and management of IP assets in Canada.

Policy framework

Defining the policy objective

As noted here and in other studies, while Canada appears to have the human capital and infrastructure to support innovation, it falls short relative to other countries in investment in R&D, patent grants and incentives to advance to the commercialization and sustainable operation stages of the innovation process. Rather, patents on a large share of inventions developed with Canadian input are assigned to foreign companies. These observations suggest that Canada faces challenges not so much in invention, but rather in IP development and commercial exploitation. In this section, we analyze various policies for addressing this challenge.

A reasonable objective for policy in this context is to maximize Canadian income, in contrast to an alternative objective, such as maximizing the number of patents retained by Canadians.[52] Using income maximization as a goal to guide the policy

[52] An example of a policy that maximizes patent retention rather than income in Canada might be one that provides a generous grant to domestic inventors who develop their IP rather than sell it to foreign firms, even if the latter would lower costs, generate greater investment and tax revenues, and employ more Canadians.

analysis, we recognize that we are operating in a second-best world with multiple market imperfections. (Indeed, patents themselves create market power that constitutes an "imperfection."[53]) Thus, we do not attempt to derive an "optimal IP policy," but instead focus on comparing the efficiency of various policies in terms of the benefits generated for, and opportunity costs incurred by, Canadians.

Inventors' decisions

In evaluating various policies, we must consider how they will affect the incentives of Canadian inventors. While the overarching policy objective is to raise national income, economic agents will naturally pursue choices to maximize their own net expected benefits or income, given their constraints and the information available.

Researchers can earn income from their inventions, broadly speaking, in three ways. First, inventors can receive income from corporations, foreign or domestic, that invest in research in Canada. Second, inventors can sell their patented inventions to companies. Third, inventors can commercially exploit their inventions through licensing and/or production. However, existing market imperfections may distort choices in ways that ultimately are socially unproductive. For example, the costs and uncertainty of defending patents in litigious environments may sway domestic patentees toward selling their IP to large companies rather than developing and commercializing it themselves.

A relatively efficient policy approach is to mitigate market imperfections faced by innovators when scaling up and to reduce the uncertainties of operating in global markets. Such policies may involve assistance with accessing essential patents, financing, managing export markets and navigating international patent applications. This is in contrast to policies that, for example, inefficiently restrict the transferability of IP to foreign owners. Doing so (through a tax on IP sales, for example) could discourage investment in innovation in Canada, in which case, Canadians would lose the benefits from employment income, knowledge acquired and financial capital from the IP sale (even if to a foreign entity) arising from domestic R&D activities.[54] We discuss a variety of policies below and identify those expected to be more effective at providing incentives for inventors to innovate, retain IP assets and develop them toward commercialization.

Policies affecting innovation, IP ownership and growth

The Canadian patent system

We begin with the patent system in Canada. Some have argued that Canadian legal protection of patents is weaker than that of the US (U.S. Chamber of Commerce 2016),

[53] In this case, an effective policy will attempt to reduce distortions created by the imperfections. Counterintuitively, it may involve adding one distortion to mitigate another. For example, consider an industrial process that creates pollution (an externality). A competitive firm does not internalize the cost of pollution and so will overproduce. In contrast, a firm with monopoly power has the incentive to increase its prices, thus reducing output and pollution. In that case, one imperfection can mitigate the other.

[54] As the CCA (2018, 164) report points out, "The extent of the economic losses to Canada depends also on the extent to which a firm's activities are relocated after its acquisition. Foreign acquisitions may not always result in a relocation of firm activities, and future growth may continue to occur in Canada. The proceeds from the sale of a business can also be reinvested in Canada, for example, funding other start-ups, thereby still contributing to local economic development."

and that patent term restoration is inadequate in the biopharmaceutical industry (Acri 2017). These criticisms have come despite the additional protections for IP that Canada accepted as part of the Comprehensive Economic and Trade Agreement with Europe (CETA) and the recent Canada-United States-Mexico Agreement (CUSMA).[55] However, the view of Canadian patent protection as weak is not universal. For example, the Global Intellectual Property Index ranks Canada's patent rights in 7th place, ahead of the US, which ranks 11th (Taylor Wessing 2016).

Would strengthening patents in Canada encourage retention, development and commercialization of Canadian-invented IP? In our view, tweaking domestic patent protection would have little effect, owing to the relatively small market in Canada. Others agree. For example, Hinton and Cowan (2017) argue: "Canadian patents are an afterthought, even for Canadian innovators," who "compete in global marketplaces where the large commercialization opportunities lie." To put this into context, since Canada represents about 2 percent of OECD countries' GDP, Canadian patents can affect only profits on this small part of the global market. Tweaking Canadian patents slightly will therefore not have much impact on investment in innovation that has global relevance. Our trading partners, however, are motivated to ask Canada to increase patent protection to benefit patentees in their countries.

Moreover, modifying Canadian IP regulations and standards will likely not have a large impact on relocating investment in innovation in Canada. The reason is that Canadian IP standards have the same protection and incentive effects on investment in innovation, regardless of where that investment takes place: a German-developed invention would benefit as much as a Canadian-developed invention from changes to the Canadian patent system. Thus, it is not apparent how changes to Canadian patents alone would drive inventive activity to Canada or significantly increase domestic innovation activity.

Canada's IP strategy

Strategies for increasing awareness and exploitation of Canada's IP have been outlined in the federal government's Intellectual Property Strategy (Innovation, Science and Economic Development Canada 2018). This is the first of its kind in Canada to highlight the central role that IP plays in innovation.

With funding of $85 million over five years, the IP Strategy sets out to increase awareness of the importance of protecting Canadian inventions, and to enhance IP expertise that can help Canadian firms capture the full benefits of their R&D investments and overcome barriers to scaling up and commercialization. To achieve these goals, the IP Strategy follows a three-pronged approach, providing (1) education and legal advice around patent

[55] The Global Intellectual Property Center of the U.S. Chamber of Commerce (U.S. Chamber of Commerce 2016, 23) notes: "Canada – which has improved its overall score in each edition of the Index – remains an outlier among high-income OECD economies. Despite increasing in each edition of the Index, Canada's score is still the lowest of all OECD economies and its national IP environment has consistently remained closer to middle-income economies such as Malaysia and Mexico than to top Index performers such as the United States and the United Kingdom." Regarding recent changes, CETA added supplementary protection certificates to extend patent term by 2 years for qualifying pharmaceutical patents and CUSMA, if implemented, will extend data protection for biologic drugs from 8 to 10 years.

practices, (2) strategic tools for inventors and (3) legal rules to enforce Canadian patent rights. We comment briefly here on two specific components: a strategic tool provided by the "patent collective" and the legal rule for mitigating trolling behaviour.

The Patent Collective

The Patent Collective pilot has been allocated $30 million of the $85 million for the IP Strategy. Although it was at an early stage of development at the time of this writing, the call for proposals by Industry, Science and Economic Development Canada stated: "The Patent Collective will help its membership better leverage IP in their drive to grow to scale and will also provide the Government with insight to better support SMEs in this regard going forward." This will be done by providing information on patents and "broader IP issues faced by SMEs" and identifying "possible opportunities for collaboration and cooperation between members to better leverage existing and available IP" (Innovation, Science and Economic Development Canada 2019, 1-2). The concept of patent collectives has been advocated in policy papers and government consultations (Clarke and Hinton 2016).

The economics literature on patent pools provides some insights as to the benefits of such collectives (Lerner and Tirole 2004; Gallini 2014). In the context of modern technologies, the development and commercialization of a product typically require multiple patentable components. Patent pools in the private sector not deemed anti-competitive by competition authorities are those that pool essential, complementary patents required for "compound" products and license them to members of the pool at a fair royalty and without fear of litigation. Typically, the members retain ownership of their patents. For firms that want to develop their technology but require multiple patents to do so, the collective, at least in theory, can reduce the cost of access to these patents and deter litigation from broad patents on inputs essential for downstream use.

Economic theory is also valuable in identifying problems with patent collectives, such as adverse selection and moral hazard (Aoki and Nagaoka 2004; Aoki and Schiff 2010). In particular, if firms can self-select into the collective, they may wish to keep their most valuable patents outside of the pool, which would leave it holding only less valuable patents. To mitigate this problem, compensation schemes must be designed to reflect the quality as well as the number of patent contributions made. Moral hazard arises when members reduce the research efforts that they agree to share with other members but, again, the design of the collective can reduce these incentives to shirk.

Also important are lessons learned from other national collectives. Clarke and Hinton (2016) examine three patent collectives, also known as Sovereign Patent Funds (SPFs), currently operating in Japan (IP Bridge), South Korea (Intellectual Discovery) and France (France Brevets). The three state-directed collectives began their operations between 2010 and 2013, with the intention of acquiring patents to pursue various objectives. Clarke and Hinton identify four types of potential objectives, which we label as (1) supportive (to provide legal advice and support to SMEs expanding into global markets); (2) defensive (to provide domestic firms with protection from litigation threats from

foreign patentees, including patent trolls); (3) financial (to facilitate commercialization and licensing of technologies so as to secure a return on their investments); and (4) patent retention (to reduce "leakage" of IP so as to preserve domestic IP assets).

South Korea's Intellectual Discovery, established in 2010, appears to have been formed around the defensive and financial objectives, to reduce the country's deficit in the IP balance of payments. Of the nearly 1,500 Intellectual Discovery patents found by Clarke and Hinton, a majority originated with Korean companies or nationals (for example, ETRI and Samsung), and 82 percent were held in the US. In contrast, the focus of France Brevets appears to be primarily financial but with a much smaller portfolio of patents, most of which are licensed in partnership with the inventor who retains ownership but licenses the patents to France Brevets with the right to sublicense. About half of the patents in this SPF are assigned in the US. Finally, Japan's IP Bridge appears to focus on support as well as financial objectives, the latter including the revival of "dormant" patents that firms may not have the incentive to develop.[56] It has a portfolio of more than 1,200 patents, 92 percent of which are assigned in the US, primarily in a few firms (for example, Sanyo and Panasonic). All three patent portfolios are concentrated in the "physics" and "electricity" categories of the International Patent Classification.

Increasing value through commercializing and licensing is a common goal across the SPFs. This is to be expected, as the collectives are likely to have greater bargaining power in negotiating licensing contracts and settlements in legal disputes. As Clarke and Hinton report, some litigation has resulted from failed licensing negotiations. The evidence, although limited, suggests that legal action taken by the SPFs has been defensive rather than offensive in nature. The patent retention objective also seems to be relevant, as the majority of patents acquired by SPFs are those owned by domestic firms with the aim of increasing their value relative to what would be earned if the patents were assigned elsewhere. While they have had some success at achieving these goals, the overall reviews of the SPFs have been mixed.[57] Nevertheless, these experimental collectives are valuable in informing architects of the new Canadian Patent Collective on how to structure its size, its selection process and, especially, its purpose.

The collective could be productive in offering legal advice to firms on overcoming barriers in securing global IP rights and scaling up their IP domestically (as with Japan's IP Bridge); or support in negotiating IP licensing contracts (as with France Brevets); or access to essential patents (research tools), and expertise on defending IP in legal battles (as with South Korea's Intellectual Discovery). Alternatively, if the risks and required capital for scaling up are too great, the collective could help Canadian inventors receive a fair return on their IP sales to large global firms. It is a work-in-progress at

[56] A case could be made for public purchase of a firm's IP assets, for example, if the market were expected to undervalue their public-good benefits to the country.

[57] Ellis (2016) argues that, while SPFs generate revenues, it is unclear whether they achieve their other goals, such as helping domestic firms scale up their operations. All appear to have slowed down further patent acquisitions while extracting a return on their current portfolio. In the case of France Brevets, Ellis claims that the goal of "kick-starting a local market in IP assets [has taken] a back seat" (12), and the collective has served a limited number of companies. Generally, in the current political climate, the SPFs are not expected to grow, especially given the modest returns to date.

this time, but, as Clarke (2017) notes, "if correctly conceived, a Canadian-focused SPF could help ameliorate…size-specific disadvantages and help firms generate revenue that could be channeled back into productive purposes."

We recommend that domestic patents in the collective be available to foreign subsidiaries registered in Canada as well as to domestic firms. Indeed, providing access to basic research tools could encourage more firms to locate and conduct research in Canada, which could have long-term benefits in developing local research talent as well as needed technical and managerial capacity.

Patent pools or other collaborations among domestic SMEs, or between SMEs and larger foreign firms with complementary assets, and in some cases cooperative agreements between potential competitors could generate benefits in the form of cost-savings and greater incentives to innovate. For example, early information sharing between firms in the pharmaceutical industry could increase incentives to scale up by eliminating wasteful duplication, reducing uncertainty of advancing to the next stage of commercial exploitation and connecting biotech start-ups with larger firms (domestic or foreign) that have complementary production and marketing capacity. The Competition Bureau recently revised its *Intellectual Property Enforcement Guidelines* (2019), providing useful information on patent pools and efficient collaborative agreements on standard-essential patents (see also Competition Bureau Canada [2009] and Federal Trade Commission and the Department of Justice [2000]). D.A. Wolfe (2018) also emphasizes the importance of collaborations through research clusters, which take advantage of a deep talent base, competition between investors to identify the most promising projects and research infrastructure including incubators and accelerators. Innovation can be best sustained within an environment that promotes it.[58]

Legal strategies toward trolls

The IP Strategy also features legislative changes to prohibit settlement demands in letters sent by trolls threatening to sue unless the alleged infringer agrees to a sizable settlement (see Bessen, Ford and Meurer 2012 and Cohen, Gurun and Kominers 2017, on trolls). This could help reduce the thicket in Canada's areas of comparative advantage and help firms enforce patents.[59] While important in protecting innovators from sham lawsuits, this legal rule would be enforceable only in Canada and, therefore, may not have much impact on incentives to retain and develop IP in Canada. Moreover, the incidence of trolling is considerably lower in Canada than in the US (where, for example, RIM was sued by NTP),[60] although recent US Supreme Court decisions and legislative changes in the *America Invents Act* (2012) are constraining nonpractising entities from engaging in aggressive patent assertion. In effect, we expect that recent legal restrictions on trolls in the US will have a greater impact on Canadian innovators' decisions than enforcement changes in Canada.

[58] D.A. Wolfe (2018) notes that such collaborations benefit from an innovation environment that "encourage[s] an open exchange of knowledge and a dynamic culture of problem-solving" (13).

[59] In particular, a "SWAT" team, or group of federal experts, will advise SMEs through litigation issues to reduce uncertainties around development and retention of their IP.

[60] However, there has been an emergence of Canadian mergers between nonpractising entities and IP service experts, such as Chipworks and TechInsights, Conversant and WiLAN, that could increase patent assertion activity in Canada (Ellis 2016).

Overall, the objectives of the IP Strategy align closely with findings in the recent literature. Therefore, it appears to be an efficient response to support innovative SMEs in Canada. However effective that support will be, especially in raising awareness of the importance of IP and providing access to essential IP, a significant infusion of human and financial capital that extends beyond this IP framework will likely be required for innovators to scale up, commercialize and compete globally. Large and diverse resources are required to expand research teams; develop infrastructure necessary for labs and production facilities; and recruit management and legal teams to connect with distributors, negotiate contracts and engage in marketing. If Canada is to become a major competitor in innovation, a greater array of public policies, beyond the provisions in the IP Strategy, will be needed. We examine some of them below.

Private-public partnerships

An important policy challenge has been in facilitating university-private partnerships in the transfer of knowledge developed within academia to private sector firms for industrial and commercial purposes (House of Commons 2017). Currently, every major university in Canada has a technology transfer office to support the process of commercializing university-developed technologies, as individual academics lack the skills to pursue patents, attract venture capital and license promising inventions. Although university-private partnerships have increased over the past five years (CCA 2018), Canada continues to lag behind in moving university-developed technologies to outside licensors. According to testimony before the House of Commons Industry Committee, Canadian universities earned only about 27 percent as much as US universities from licensing revenues on a normalized basis.[61] In "clean technology," for example, US firms are reported to patent 2.3 times more per academic publication than Canadians. China patents 15 times more per academic publication than Canada (Duruflé and Carbonneau 2016).

The propensity to license depends on the propensity to patent since, without property rights, users of the technology can simply copy it. In turn, the propensity to patent may depend, in part, on the ownership agreements between the university and the researcher. The US *Bayh-Dole Act* (1980) gives universities property rights on inventions supported by public funds, although they can reallocate or share the property rights with the researchers. In Canada, ownership varies considerably across universities, with some universities owning the IP but granting a nonexclusive licence to creators (University of British Columbia), while others use joint ownership (University of Toronto, McGill University) or creator-owned IP (University of Waterloo, McMaster University, Western University).

While incentives to innovate and license depend on the nature of IP rights, at least in theory, it remains to be determined empirically the extent to which they explain the US-Canadian differences in university licensing activity. Factors other than IP ownership are relevant. For example, the CCA (2018) report shows that the areas of comparative advantage in academic research do not always align with those in industry in Canada. Nevertheless, it finds that productive alliances between universities and the

[61] Stephen Susalka, Association of University Technology Managers, Standing Committee on Industry, Science and Technology, June 6, 2017, https://www.ourcommons.ca/DocumentViewer/en/42-1/INDU/meeting-65/evidence.

private sector have increased over the past five years. This is an important area for future research, but more data are required on the nature of licensing contracts; the set of patents invented and retained across Canadian universities; those that have been developed further, licensed, commercialized or sold; and the technology areas and value (based, for example, on citation data) of those patents.

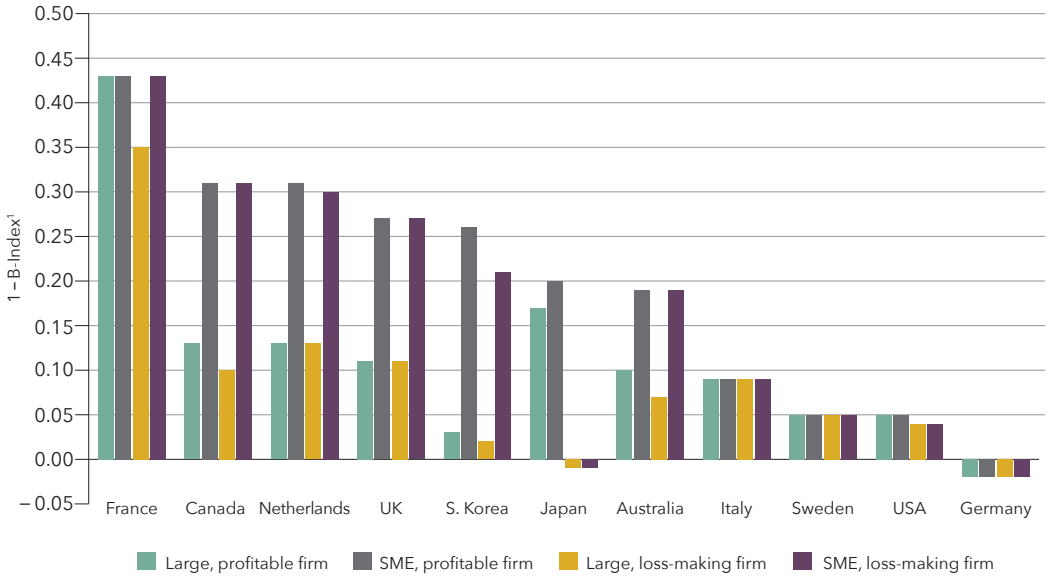
Tax credits and subsidies

Tax credits and subsidies for research represent an important complement to IP for supporting innovation. We discuss them separately.

Tax credits

The main public financial support to Canadian companies engaged in research is the Scientific Research and Experimental Development Tax Incentive Program (SR&ED). SR&ED provides tax credits for qualifying R&D expenditures at a rate of 35 percent to Canadian-controlled private companies and 15 percent to other companies (Canada n.d.). Tax credits for research differ across countries, according to the set of eligible expenses, size of the credit and size of the firm receiving benefits, and profitability levels required to earn the full credit. Accounting for these differences, the OECD compares tax subsidy rates across countries, using the 1-B-Index to reflect the effect on representative firms (OECD 2017b). As shown in figure 16, compared with peer countries, Canada is relatively generous in its support of research through tax credits.

Figure 16. Tax subsidy rates for business expenditures on R&D by firm size and profitability, selected countries, 2017



Source: OECD, "R&D tax expenditure and direct government funding of BERD," https://stats.oecd.org/Index.aspx?DataSetCode=RDTAX.

[1] The 1 – B-Index is the tax subsidy rate on R&D expenditures. The OECD defines the B-Index as "a measure of the level of pre-tax profit a 'representative' company needs to generate to break even on a marginal, unitary outlay on R&D, taking into account provisions in the tax system that allow for special treatment of R&D expenditures" (OECD 2014, figure 1.10).

Note: Data on tax support are not available for Israel.

There are significant differences between the treatment of large and small firms, with Canada ranking second in tax credit support for small firms and fourth for large firms. The OECD data, however, include only federal tax relief. Provinces also provide tax subsidies for innovation, which historically have accounted for approximately 30 percent of total tax support (OECD 2018a; Mackenzie 2005). Therefore, when we consider both provincial and federal tax support, Canada appears to be a relatively strong supporter of innovation in smaller businesses and a moderately strong supporter of innovation in large businesses.[62]

Direct funding

Governments also provide direct support to companies. The OECD measures the amount of business R&D funded by the government as reported by firms. These data include contracts, loans, grants and subsidies.[63] Figure 17 shows total government support for business R&D, both directly and through tax incentives as a share of GDP. (Recall that only federal tax incentives are included.) It is striking that for comparable countries (excluding Israel, for which tax support data are not available), government funding for R&D is approximately five times higher in France (where support is the highest) than in Germany (where it is the lowest), with Canada ranked in the bottom half. As noted earlier, Canada ranks high on tax incentives but relatively low on direct government funding.[64]

Complementary to this is figure 18, which shows direct government support for business R&D as a percentage of GDP on the horizontal axis, and business expenditures on R&D (BERD) on the vertical axis. The size of the bubbles is proportional to the number of USPTO patents per $100 billion in GDP. While patenting is clearly related to BERD, the relationship between each of these variables and direct government support, all admittedly endogenous variables, appears to be strong. In particular, for this sample of countries, the correlation between direct government funding to business as a share of GDP and total patents per GDP is 0.66 (p = 0.02), indicating that direct funding is at least significantly associated with innovation output. Of course, correlations do not imply causality: for instance, it may be that the high level of innovation led to greater lobbying for more direct funding for promising research projects.

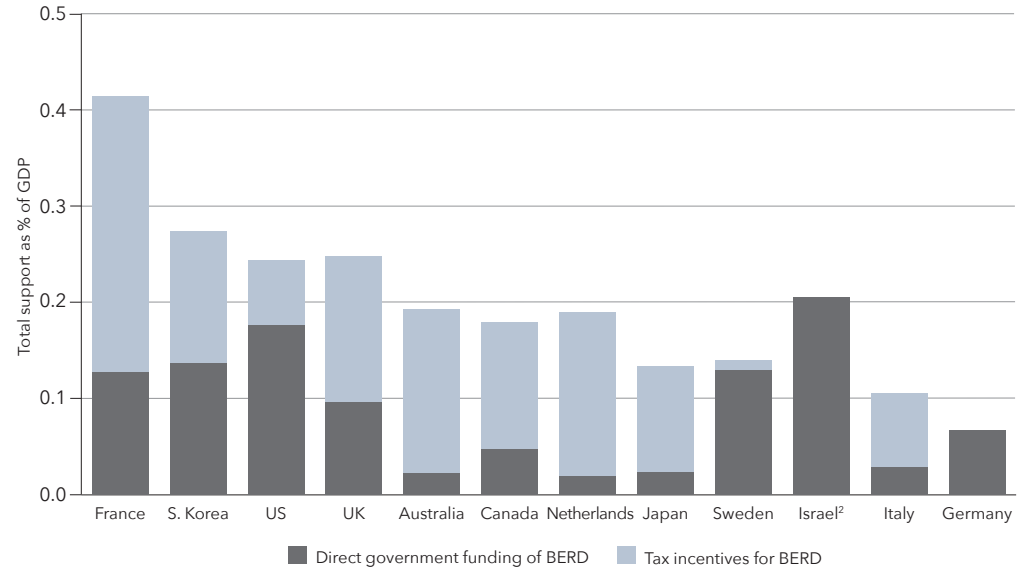
The relationship between total government funding and patents per GDP is less apparent, with a statistically insignificant correlation of 0.13 (p = 0.70) (excluding Israel). The observation that patent activity is significantly correlated with *direct* government support but has no discernible relationship with *total* government support suggests

[62] Views on the costs and benefits of the SR&ED program are mixed. Parsons and Phillips (2007) estimate that the program has a net return of approximately 11 percent, and Czarnitzki, Hanel and Rosa (2011) perform an econometric analysis, showing that the program increases innovation by recipient firms. Others argue that since the cost of the program is substantial and must be funded through increased taxes, it may be better to distribute the tax credit more evenly across innovating firms, rather than having very high tax credits only for small firms (Bibbee 2012). Pantaleo, Poschmann and Wilkie (2013) propose that tax credits should be reallocated to support scale-up of inventions, rather than subsidizing small business R&D.

[63] For more information, see OECD (2010).

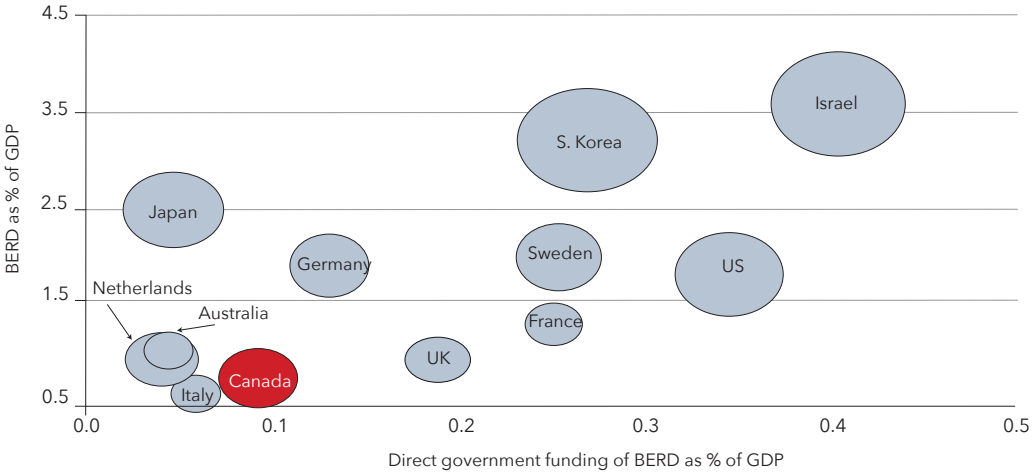
[64] This direct-indirect funding difference has been addressed in other studies; see, for example, Science, Technology and Innovation Council (2015).

Figure 17. Total government support (direct and indirect)[1] for business R&D, selected countries, 2016



Source: OECD, "R&D tax expenditure and direct government funding of BERD," https://stats.oecd.org/Index.aspx?DataSetCode=RDTAX.
[1] Indirect support is government support through R&D tax incentives.
[2] Tax support data for Israel are not available.
BERD = business expenditures on R&D

Figure 18. The relationship among patenting, direct government support and business expenditures on R&D, selected countries, 2017



Sources: OECD, "Measuring Tax Support for R&D and Innovation," http://www.oecd.org/sti/rd-tax-stats.htm; and US Patent and Trademark Office, "USPTO Patent Full-Text and Image Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm; World Bank national accounts data and OECD National Accounts data files, "GDP (constant 2010 US$," https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?.
Note: Bubble size varies according to number of patents per $100 billion GDP.
BERD = business expenditures on R&D

that the mix of funding (direct, indirect) may matter. For example, Germany and Sweden perform as well or better than Canada with less total government funding, but their funding is more heavily weighted toward direct funding. Although government funding per GDP in high innovation output countries such as the US and the Republic of Korea is significantly greater than in Canada, so too is their reliance on direct rather than indirect funding. In contrast, governments in countries such as France and Australia that have relatively low patenting activity provide significant total support, but the funding is weighted toward tax credits as in Canada.

Canada appears to fall in the bottom half of the pack in government support of R&D, with a direct/indirect funding ratio that appears to align more closely with the low-output countries. While these observations are far from conclusive, they are sufficiently interesting to warrant deeper analysis, both theoretically and empirically, of the various approaches to funding innovation, and whether an increase in direct funding, possibly trading off lower tax credits, could make Canada more competitive.[65] Indeed, the impact of the government's recent commitment to invest over $1 billion in research superclusters, AI labs, incubators and accelerators will be an important input into such a study.[66]

Patent (or innovation) box

The patent box is another tax-related policy, implemented in several countries including Ireland, France and the Netherlands, under various names. It was recommended during the consultation process for Canada's IP Strategy but not adopted.[67] The patent box is a tax incentive that lowers the corporate tax on profits earned from IP assets researched and developed in Canada. In providing incentives directed at the output of IP – the development and commercialization of Canadian-owned IP – rather than the input of IP or research activity, a patent box policy would complement the current SR&ED tax credit. Robson, Laurin and Wyonch (2017) suggest that a patent box could have the "benefit of incentivizing production related to Canadian patents to remain within our borders."

Note that the patent box could affect incentives to create new products and processes as well as to adopt them. In providing direct incentives to IP owners by taxing their profits from developing and commercializing of IP at a lower rate, the patent box may have the beneficial effect of reducing the marginal cost of production and, therefore, the price of the technology to adopters of technology. This is important because Canadian businesses show a relatively low propensity to adopt new technologies in production.

Technology adoption in Canada

While this study has focused on the role of patents in driving the supply of innovation in Canada, the creation of innovation depends fundamentally on demand, especially, as we argue, global demand. Global adoption of technology is essential in spurring

[65] See also Guellec and van Pottelsberghe de la Potterie (2013), who argue that tax credits and direct funding are substitutes in supporting innovation but do not analyze their relative efficiency.
[66] For example, the federal government has committed to invest $950 million in superclusters, as well as $250 million for AI labs such as the Vector Institute (Hinton and Cowan 2018). However, this funding will not translate into commercialization without a "strategy for growth."
[67] See Parsons (2011) for further discussion of the patent (innovation) box.

innovation, but also in providing the productive feedback for new improvements, new uses of the invention or entirely new products or processes (CCA 2018; Dutz, Kuznetsov, Lasagabaster and Pilat 2014).

Domestic demand for (or adoption of) cutting-edge technologies also matters a great deal to innovation in Canada. Service and manufacturing industries that implement state-of-the-art technologies can reduce costs, increase labour productivity and generate new "innovation" – perhaps not patented products, but innovations in the form of better systems for allocating workers' time, and more efficient inventory, financial and management processes. That is, high productivity and growth in Canada depend not only on the generation of cutting-edge products and processes, but also on adopting them in manufacturing and services. While Canadian demand may not provide sufficient impetus to develop new patentable products and processes, domestic adoption of them in manufacturing and services can generate additional nonpatentable innovations.

Unfortunately, Canada fares poorly in the adoption of cutting-edge technologies. For example, a paper for the Conference Board of Canada (Dimick 2014) reports that Canadian businesses show a low propensity to adopt digital technologies. Other research shows that, relative to peer countries, Canadian firms have been slow to adopt various technologies, including robotics, cloud computing and radio-frequency identification (OECD 2017a,c). Why is that the case and what might be done about it? Although this study does not address that question, we note that some of the structural factors identified here as barriers to scaling up IP (for example, uncertainty around patent infringement) may also be at play in adoption. Similarly, policies proposed by the IP Strategy, tax credits, direct funding and other policies that directly affect R&D incentives can encourage adoption, for example, by lowering the cost of essential inputs. In any event, understanding why Canadian manufacturing and service sectors are less inclined to adopt new technologies relative to their counterparts remains an important area for future research.

CONCLUSIONS

In this study, we have examined the role that patents play in Canadians' decisions to commercialize and scale up their innovations. We have argued that patents are a key tool for firms, especially SMEs, to advance in the innovation process. By establishing a property right through patents, innovators are better able to signal their invention's value to obtain financing, ward off competition and protect themselves from trolls. However, patents can also be a deterrent to scale-up for SMEs, when held by other (large) firms on essential inputs for product development. The costs of accessing those patents, through either royalties or legal battles, may simply be too great for a small firm to overcome.

We recognize that not every invention needs to be exploited through patenting. Banting and Best's decision to not exploit patent rights for insulin is an important example of this in Canadian history, and we can also see attempts to make progress

without IP in the small open-source biotech firm M4K Pharma (Edwards and Hollis 2018). However, patents have become increasingly important, especially for SMEs, for competing in many global, knowledge-based technologies.

Canada has many of the right conditions for innovation: well-educated workers, strong research institutions, attractive immigration opportunities for skilled workers, an active venture capital scene, generous R&D tax credits and close access to the large US market. Yet its record on patent output is modest at best. For instance, we observe that Canadians are heavily involved in innovations that are ultimately patented in the US. Indeed, a notable feature of the Canadian innovation landscape is a propensity to assign Canadian-invented IP to foreign firms rather than retain it for further development. Compared with peer countries, we note some erosion in Canada's ranking between "Canadian-invented" patents and "Canadian-owned" patents, even in areas of technological strength for the country.

In attempting to understand Canadian inventors' incentives for assigning/selling their patents rather than scaling up/commercializing, our study builds on economic research and related policy studies in the area. With its focus on patents – one of several elements required to scale up – it complements and contributes to that literature. In particular, we examine more deeply the conditions and potential barriers in the innovation, technology and product markets that make selling patents a more profitable option than commercializing the product protected by the IP. Focusing on inventions with potential for global reach, as represented by the US, the largest and most lucrative market in which to operate, we identify particular demand and supply factors that contribute to the sale of Canadian-invented IP:

Demand for Canadian IP – The proximity of Canada to the US and similarity in language and culture make Canadian firms, with their IP assets and research teams, attractive targets for purchase. The incentive to buy rather than license Canadian IP assets is especially strong for vertically integrated firms, which are dominant in the US industrial knowledge-based landscape.

Supply of Canadian IP – The US market has become more complex and litigious to operate in, resulting in potentially high negotiation and licensing costs of acquiring essential inputs for commercial exploitation. The incentive to sell rather than scale up has also increased with the rise of dominant, vertically integrated firms that are both fierce competitors in selling goods and services and potential buyers of IP.

These structural and institutional features of the innovation environment in which Canadian firms operate have important implications in terms of policy strategy and options. While they may discourage Canadians from competing in the US market, they may also provide opportunities for valuable cooperation. In particular, Canadians may benefit from investments in research facilities by foreign subsidiaries in Canada. In addition to supporting employment, foreign innovative investment can help develop valuable entrepreneurial expertise, identified in other reports to be lacking in Canada. While the IP ultimately would rest with the foreign subsidiary/parent, the talent and

scientific infrastructure developed could generate long-term and sustainable benefits in Canada, relative to alternative, less desirable outcomes: exodus of Canadian talent, low investment and fewer high-paying jobs.

For the same reasons, we would caution against introducing policies aimed directly at retaining IP in Canada, such as taxes on international transfers, as they could be counterproductive for research. In some areas, the social return on investment from a policy that supports early-stage research, even if the IP is ultimately sold to foreign buyers, may be larger than the return on a policy that supports domestic scale-up but requires significantly more resources.

In some areas, however, policies directed at reducing bottlenecks of operating in global markets could tip the sell-versus-scale-up balance toward the latter, while increasing both the social return on investment and incentives to engage in commercial exploitation. For example, promising measures are being implemented as part of Canada's IP Strategy to provide legal expertise in negotiating global markets, reduce search costs of identifying prior art and overlapping patents, create patent collectives to facilitate access to essential knowledge and restrict wasteful litigation brought on by patent trolls. The IP Strategy does not include policies for broadening or strengthening patent protection in Canada (other than legal action against trolls). We believe this is the correct approach, as we have not found evidence that altering Canadian patent law would significantly increase innovation activity in Canada.

While the IP Strategy has the potential to raise awareness of the centrality of IP to the innovation process and to reduce barriers in global markets, we recognize that more will be required for innovators to retain their IP and pursue the path of commercial exploitation. If Canada is to become a major competitor in innovation, a greater array of public policies and tax incentives will be required.

Further research is clearly needed to understand more fully why Canada falls short in exploiting its inventive capacity, and to identify efficient policies that will help maximize Canada's return from its innovation investment. Toward that objective, we put forward the following research questions that arise from our analysis.

- Under what conditions are Canadian-invented patents assigned to Canadian residents when the patent is first granted? With a small sample, we showed that patents were more likely to be assigned to Canadian residents when the research team included a greater proportion of Canadians. The sample was small, however, and we did not control for the size of the team, the technology area or the quality of the invention. A better understanding of the invention assignment data could help us identify the areas of Canada's comparative strengths and potential barriers to patent acquisition.
- Under what conditions are those Canadian-invented and Canadian-assigned patents then reassigned to foreign firms in the subsequent 10 to15 years? We tracked the patterns of sales for a small sample of patents retained in Canada over a 10-year period and found that a significant proportion are eventually

sold to foreign firms. However, a larger study that follows the evolution of Canadian IP reassignments by whom and to whom, in what technology areas and at what stages of development would provide valuable information on Canada's scale-up potential.

- How important is the mix of direct public funding and tax credits to the innovation process? A cursory examination of OECD data reveals a low correlation between total government support and both business R&D spending and patenting. In contrast, direct funding appears to be more closely associated with patenting across peer countries than indirect support (for example, tax credits). In order to inform sound policy, a causal model should be developed that will estimate how effective the different forms of government support are in motivating innovators to develop and commercialize their IP and compete in global markets.

REFERENCES

Acri, K. 2017. "Implications of the Proposed Changes to Canada's Pharmaceutical Pricing Regulations." Vancouver: Fraser Institute. https://www.fraserinstitute.org/studies/implications-of-the-proposed-changes-to-canadas-pharmaceutical-pricing-regulations

Advisory Panel for the Review of Federal Support for Fundamental Science. 2017. *Investing in Canada's Future: Strengthening the Foundations of Canadian Research*. Ottawa: Innovation, Science and Economic Development Canada. http://www.sciencereview.ca/eic/site/059.nsf/vwapj/ScienceReview_April2017.pdf/$file/ScienceReview_April2017.pdf

Ahern, K.R., D. Daminelli, and C. Fracassi. 2015. "Lost in Translation? The Effect of Cultural Values on Mergers Around the World." *Journal of Financial Economics* 117: 165-89.

Aoki, R., and S. Nagaoka. 2004. "The Consortium Standard and Patent Pools." *Economic Review* 55 (4): 345-57. https://ideas.repec.org/a/hit/ecorev/v55y2004i4p345-357.html

Aoki, R., and A. Schiff. 2010. "Intellectual Property Clearinghouses: The Effects of Reduced Transaction Costs in Licensing." *Information Economics and Policy* 22 (3): 218-27. https://ideas.repec.org/a/eee/iepoli/v22y2010i3p218-227.html

Autor, D., D. Dorn, L.F. Katz, C. Patterson, and J. Van Reenen. 2017. "The Fall of the Labor Share and the Rise of Superstar Firms." Working paper, MIT, May 1. http://economics.mit.edu/files/12979

Balsillie, J. 2018. "Canadians Can Innovate, but We're Not Equipped to Win." *Globe and Mail*, May 15.

Barnett, J. 2017. "Patent Tigers: The New Geography of Global Innovation." Working paper, University of Southern California, Los Angeles.

Bessen, J., and M.J. Meurer. 2008. *Patent Failure: How Judges, Bureaucrats, and Lawyers Put Innovators at Risk*. Princeton, NJ: Princeton University Press.

Bessen, J., J. Ford, and M. Meurer. 2012. "The Private and Social Costs of Patent Trolls." *Regulation* 34 (4): 26-35.

Bibbee, A. 2012. *Unleashing Business Innovation in Canada*. Paris: Organisation for Economic Co-operation and Development.

Blit, J. 2017. "Toward an Optimal Patent Regime for Canada." Waterloo: Centre for International Governance Innovation. https://www.cigionline.org/articles/toward-optimal-patent-regime-canada

Boldrin, M., and D.K. Levine. 2008. "Perfectly Competitive Innovation." *Journal of Monetary Economics* 55 (3): 435-53.

Breznitz, D., and D. Ornston. 2014. "Scaling Up and Sustaining Experimental Innovation Policies with Limited Resources: Peripheral Schumpeterian Development Agencies." In *Making Innovation Policy Work: Learning from Experimentation*, edited by M.A. Dutz, Y. Kuznetsov, E. Lasagabaster, and D. Pilat. Paris: Organisation for Economic Co-operation and Development. https://read.oecd-ilibrary.org/science-and-technology/making-innovation-policy-work_9789264185739-en#page248

Buch, C.M., and G. DeLong. 2004. "Cross-border Bank Mergers: What Lures the Rare Animal?" *Journal of Banking & Finance* 28 (9): 2077-102.

Canada. n.d. "Claim SR&ED Tax Incentives — What Are the Tax Incentives." https:// www.canada.ca/en/revenue-agency/services/scientific-research-experimental-development-tax-incentive-program/claim-sred-tax-incentive-what-tax-incentive.html

Canadian Intellectual Property Office. n.d. *A Guide to Patents*. https://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/h_wr03652.html

Clarke, W. 2017. "A Worthwhile Intervention? The Potential Role for a Sovereign Patent Fund in Canada." Waterloo: Centre for International Governance Innovation. https://www.cigionline.org/articles/worthwhile-intervention-potential-role-sovereign-patent-fund-canada

Clarke, W., and J.W. Hinton. 2016. "Mobilizing National Innovation Assets: Understanding the Role of Sovereign Patent Funds." Waterloo: Deep Centre for Digital Entrepreneurship and Economic Performance.

Cohen, L.H., U.G. Gurun, and S.D. Kominers. 2017. "Patent Trolls: Evidence from Targeted Firms." Harvard Business School Finance Working Paper 15-002, Boston.

Competition Bureau Canada. 2009. *Competitor Collaboration Guidelines*. https://www.competitionbureau.gc.ca/eic/site/cb-bc.Nsf/eng/03177.html

——. 2019. *Intellectual Property Enforcement Guidelines*. https://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/eng/04421.html

Conference Board of Canada. 2018. "Provincial and Territorial Ranking: Innovation." How Canada Performs. https://www.conferenceboard.ca/hcp/provincial/innovation.aspx

Council of Canadian Academies. 2013. *The State of Industrial R&D in Canada*. Ottawa: Expert Panel on Industrial R&D in Canada, Council of Canadian Academies. https://cca-reports.ca/wp-content/uploads/2018/10/ird_fullreporten.pdf

——. 2018. *Competing in a Global Innovation Economy: The Current State of R&D in Canada*. Ottawa: Expert Panel on the State of Science and Technology and Industrial Research and Development in Canada, Council of Canadian Academies. https://cca-reports.ca/wp-content/ uploads/2018/09/Competing_in_a_Global_Innovation_Economy_FullReport_EN.pdf

Czarnitzki, D., P. Hanel, and J.M. Rosa. 2011. "Evaluating the Impact of R&D Tax Credits on Innovation: A Microeconometric Study on Canadian Firms." *Research Policy* 40 (2): 217-29.

Dickinson, H.W., and J. Rhys. 1927. *James Watt and the Steam Engine*. Oxford, UK: Clarendon Press.

Dimick, S. 2014. *Adopting Digital Technologies: The Path for SMEs*. Conference Board of Canada Briefing. https://www.conferenceboard.ca/e-library/abstract.aspx?did=6029&AspxAutoDetectCookieSupport=1

DueNorth BioDev Corp. 2018. "What We Do." Ottawa. https://www.duenorthbiodev.com/what-we-do

Duruflé, G., and L. Carbonneau. 2016. *Forging a Cleaner and More Innovative Economy in Canada: The Challenges of the Financing Chain to Foster Innovation and Growth in the Clean Tech Sector*. Produced by Cycle Capita Management and Sustainable Development Technology Canada, in collaboration with écotech Québec. https://www.sdtc.ca/wp-content/uploads/2018/01/forgingacleanerandmoreinnovativeeconomyincanada.pdf

Dutta, S., B. Lanvin, and S. Wunsch-Vincent, eds. 2018. *World Innovation Index: Energizing the World with Innovation*. Ithaca, Fontainebleau and Geneva: Cornell University, INSEAD and the World Intellectual Property Organization.

Dutz, M., Y. Kuznetsov, E. Lasagabaster, and D. Pilat, eds. 2014. *Making Innovation Policy Work: Learning from Experimentation*. Paris: OECD Publishing. https://read.oecd-ilibrary.org/science-and-technology/making-innovation-policy-work_9789264185739-en#page1

Eckert, A., C. Langinier, and L. Zhao. 2018. "Determinants of Locational Patenting Behaviour of Canadian Firms." Working paper, University of Alberta, May.

Edwards, A., and A. Hollis. 2018. "Open Source Drug Discovery." Canadian Science Policy Centre. https://sciencepolicy.ca/news/open-source-drug-discovery

Ellis, J. 2016. "New Priorities and Strategies for Sovereign Patent Funds." *Intellectual Asset Management*. Sovereign Issue, November/December: 9-15.

Farre-Mensa, J., D. Hegde, and A. Ljungqvist. 2016. "The Bright Side of Patents." NBER Working Paper 21959. Cambridge, MA: National Bureau of Economic Research. https://www.nber.org/papers/w21959.pdf

——. 2017. "What Is a Patent Worth? Evidence from the U.S. Patent Lottery." NBER Working Paper 23268. Cambridge, MA: National Bureau of Economic Research. https://www.nber.org/papers/w23268.pdf

Feldman, R., and M. Lemley. 2015. "Do Patent Licensing Demands Mean Innovation?" *Iowa Law Review* 101: 137-89.

Federal Trade Commission and the US Department of Justice. 2000. *Antitrust Guidelines for Collaborations among Competitors*. April. https://www.ftc.gov/sites/default/files/documents/public_events/joint-venture-hearings-antitrust-guidelines-collaboration-among-competitors/ftcdojguidelines-2.pdf

Feng, J., and X. Jaravel. 2016. "Who Feeds the Trolls? Patent Trolls and the Patent Examination Process." Working paper, Harvard University, July.

Funding Universe. n.d. "QLT Inc. History." http://www.fundinguniverse.com/company-histories/qlt-inc-history/

Galasso, A., and M. Schankerman. 2015. "Patents and Cumulative Innovation: Causal Evidence from the Courts." *Quarterly Journal of Economics* 130 (1): 317-69.

——. 2018. "Patent Rights, Innovation and Firm Exit." *RAND Journal of Economics* 49 (1): 64-86.

Galasso, A., M. Schankerman, and C.J. Serrano. 2013. "Trading and Enforcing Patent Rights." *RAND Journal of Economics* 44 (2): 275-312.

Gallini, N. 2002. "The Economics of Patents: Lessons from Recent U.S. Patent Reform." *Journal of Economic Perspectives* 16 (2): 131-54.

——. 2014. "Cooperating with Competitors: Patent Pooling and Choice of a New Standard." *International Journal of Industrial Organization* 36: 4-21.

——. 2017. "Do Patents Work? Thickets, Trolls and Antibiotic Resistance." *Canadian Journal of Economics* 50 (4): 893-926.

Greenspon, J., and E. Rodigues. 2017. *Are Trends in Patenting Reflective of Innovative Activity in Canada?* CSLS Research Report 2017-02. Ottawa: Centre for the Study of Living Standards.

Guellec, D., and B. van Pottelsberghe de la Potterie. 2013. "The Impact of Public R&D Expenditure on Business R&D." *Economics of Innovation and New Technology* 12 (3): 225-43.

Hall, B.H., C. Helmers, and G. von Graevenitz. 2015. "Technology Entry in the Presence of Patent Thickets." NBER Working Paper w21455. Cambridge, MA: National Bureau of Economic Research.

——. 2016. "Patent Thickets and First-Time Patenting: New Evidence." Centre for Economic Policy Research. https://voxeu.org/article/patent-thickets-and-first-time-patenting-new-evidence

Heller, M.A., and Eisenberg, R.S. 1998. "Can Patents Deter Innovation? The Anticommons in Biomedical Research." *Science* 280 (5364): 698-701.

Henry, M.D., and J.L. Turner. 2006. "The Court of Appeals for the Federal Circuit's Impact on Patent Litigation." *Journal of Legal Studies* 35 (1): 85-117.

Hinton, J., and P. Cowan. 2017. "Canada Needs an Innovative Intellectual Property Strategy." *Globe and Mail*, May 19.

——. 2018. "Canada's IP Strategy Is Not in Step with Our Innovation and Commercialization Goals." *Globe and Mail*, November 25.

House of Commons. 2017. Standing Committee on Industry, Science and Technology. *Intellectual Property and Technology Transfer: Promoting Best Practices*. D. Ruimy, chair. https://www.ourcommons.ca/Content/Committee/421/INDU/Reports/RP9261888/indurp08/indurp08-e.pdf

Industry Canada. 2016. "Key Small Business Statistics – June 2016." https://www.ic.gc.ca/eic/site/061.nsf/eng/h_03018.html#point5-1

Innovation, Science and Economic Development Canada. 2018. *Intellectual Property Strategy*. https://www.ic.gc.ca/eic/site/108.nsf/eng/home

——. 2019. *Patent Collective Program Guide*. Intellectual Property Strategy. https://www.ic.gc.ca/eic/site/135.nsf/vwapj/00001-eng.pdf/$file/00001-eng.pdf

Jaffe, A.B., and J. Lerner. 2004. *Innovations and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do about It*. Princeton, NJ: Princeton University Press.

Jenkins, T., B. Dahlby, A. Gupta, M. Leroux, D. Naylor, and N. Robinson. 2011. *Innovation Canada: A Call to Action. Review of Federal Support to Research and Development – Expert Panel Report*. Ottawa: Industry Canada.

Knight Therapeutics. n.d. "Overview." https://www.gud-knight.com/overview/

KU News Service. 2016. "Professor Analyzing Decades of Data to Determine Patent Value." August 30. https://today.ku.edu/mk%20patent

Lanjouw, J., and M. Schankerman. 2004. "Protecting Intellectual Property Rights: Are Small Firms Handicapped?" *Journal of Law and Economics* 47 (1): 45-74.

Lemley, M., and R. Feldman. 2016. "Patent Licensing, Technology Transfer, and Innovation." *American Economic Review* 106 (5): 188-92.

——. 2018. "Is Patent Enforcement Efficient?" *Boston University Law Review* 98: 101-19.

Lemley, M., and C. Shapiro. 2005. "Probabilistic Patents." *Journal of Economic Perspectives* 19 (2): 75-98.

Lerner, J. 1995. "Patenting in the Shadow of Competitors." *Journal of Law and Economics* 38 (2): 463-95.

Lerner, J., and J. Tirole. 2004. "Efficient Patent Pools." *American Economic Review* 94 (3): 691-711.

Mackenzie, K. 2005. "Tax Subsidies for R&D in Canadian Provinces." *Canadian Public Policy* 31 (1): 29-44.

McKenna, B., and J. Torobin. 2010. "Canada's Sorry State of Innovation." *Globe and Mail*, October 8.

Mezzanotti, F. 2015. "Roadblock to Innovation: The Role of Patent Litigation in Corporate R&D." Northwestern University Working Paper, January, Chicago.

Mokyr, J. 1990. *The Lever of Riches: Technological Creativity and Economic Progress*. Oxford, UK: Oxford University Press.

Murray, F., and S. Stern. 2007. "Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge? An Empirical Test of the Anti-Commons Hypothesis." *Journal of Economic Behavior and Organization* 63 (4): 648-87.

OECD. 2010. *Measuring Innovation: A New Perspective*. Paris: OECD Publishing.

——. 2014. *OECD Economic Surveys: Spain*. OECD Publishing. http://doi.org/10.1787/eco_surveys-esp-2014-en

——. 2017a. *ICT Access and Usage by Businesses Database*. July. http://oe.cd/bus

——. 2017b. *OECD Review of National R&D Tax Incentives and Estimates of R&D Tax Subsidy Rates*. http://www.oecd.org/sti/rd-tax-stats-design-subsidy.pdf

——. 2017c. *OECD Science, Technology and Industry Scoreboard 2017: The Digital Transformation*. https://doi.org/10.1787/9789264268821-en

——. 2018a. *OECD Time-series Estimates of Government Tax Relief for Business R&D*. https:// www.oecd.org/sti/rd-tax-stats-tax-expenditures.pdf

——. 2018b. *The Oslo Manual: Guidelines for Collecting, Reporting and Using Data on Innovation*. 4th edition. https://doi.org/10.1787/9789264304604-en

Pantaleo, N., F. Poschmann, and S. Wilkie. 2013. *Improving the Tax Treatment of Intellectual Property Income in Canada*. C.D. Howe Institute Commentary 379. Toronto: C.D. Howe Institute. https://www.cdhowe.org/sites/default/files/attachments/research_papers/mixed/Commentary_379_0.pdf

Parsons, M. 2011. *Rewarding Innovation: Improving Federal Support for Business R&D in Canada*. C.D. Howe Institute Commentary 334. Toronto: C.D. Howe Institute. https://www.cdhowe.org/ sites/default/files/attachments/research_papers/mixed/Commentary_334_0.pdf

Parsons, M., and N. Phillips. 2007. "An Evaluation of the Federal Tax Credit for Scientific Research and Experimental Development." Department of Finance Working Paper 2007-08, September. Ottawa: Department of Finance.

Perry, S. J., and T.A. Currier. 2014. *Canadian Patent Law*. 2nd edition. Toronto: LexisNexis Canada.

Plant, C. 2017. "Canada's Patent Puzzle." Impact Centre, Venture Analytics, University of Toronto, May.

Rai, A.K. 2007. "Knowledge Commons: The Case of the Biopharmaceutical Industry." *First Monday* 12 (6), June 4. https://firstmonday.org/ojs/index.php/fm/article/view/1909/1791

Robson, W.B.P., A. Laurin, and R. Wyonch. 2017. *Getting Real: A Shadow Federal Budget for 2017*. C.D. Howe Institute Commentary 470. https://www.cdhowe.org/sites/default/files/attachments/research_papers/mixed/Commentary_470.pdf.

Rush, S., G. Chin, and A. Kaikai. 2016. "Software Patent Eligibility in Canada: IP Year in Review." *Canadian Lawyer*, December 29. https://www.canadianlawyermag.com/article/software-patent-eligibility-in-canada-ip-year-in-review-3474/

Sampat, B., and H.L. Williams. 2019. "How Do Patents Affect Follow-on Innovation? Evidence from the Human Genome." *American Economic Review* 109 (1): 203-36. https://www.aeaweb.org/articles?id=10.1257/aer.20151398&&from=f

Schwanen, D., and R. Wyonch. 2018. *Canada's 2018 Innovation Policy Report Card*. Toronto: C.D. Howe Institute.

Science, Technology and Innovation Council. 2015. *Canada's Innovation Challenges and Opportunities*. State of the Nation 2014. Canada's Science, Technology and Innovation System. Ottawa. http://www.stic-csti.ca/eic/site/stic-csti.nsf/vwapj/STIC_1500_SON_Report_e_proof4. pdf/$file/STIC_1500_SON_Report_e_proof4.pdf

Scotchmer, S. 1991. "Standing on the Shoulders of Giants: Cumulative Research and the Patent Law." *Journal of Economic Perspectives* 5 (1): 29-41.

Shambaugh, J., R. Nunn, and B. Portman. 2017. *Eleven Facts about Innovation and Patents*. The Hamilton Project. Washington, DC: Brookings Institution. https://www.brookings.edu/wp-content/uploads/2017/12/thp_20171213_eleven_facts_innovation_patents.pdf

Taylor Wessing. 2016. *Global Intellectual Property Index*. 5th report. https://united-kingdom.taylorwessing.com/documents/get/576/gipi5-report.pdf

TEC Edmonton. 2017a. *Annual Report 2016-2017*. https://www.tecedmonton.com/wp-content/uploads/2019/02/TEC-2016-17-Annual-Report.pdf

——. 2017b. "Tevosol Achieves US Patent Protection for Organ Transplant Device." https://www.tecedmonton.com/tevosol-achieves-us-patent-protection-for-organ-transplant-device/

Torrance, A.W., and J.D. West. 2017. "All Patents Great and Small: A Big Data Network Approach to Valuation." *Virginia Journal of Law and Technology* 20 (3): 468-504.

Ubelacker, S. 2016. "Status of Gene Patents in Canada Unresolved, Despite Successful Challenge." Canadian Press, March 20. https://www.ctvnews.ca/health/status-of-gene-patents-in-canada-unresolved-despite-successful-challenge-1.2824957

United States Patent and Trademark Office. n.d. "Patent Counts by Origin and Type: Calendar Year 2015." https://www.uspto.gov/web/offices/ac/ido/oeip/taf/st_co_15.htm

U.S. Chamber of Commerce. 2016. *Infinite Possibilities: U.S. Chamber International IP Index*. 4th edition. Global Intellectual Property Center. Washington, DC: Global Intellectual Property Center. https://www.theglobalipcenter.com/wp-content/uploads/2017/04/GIPC_Index_Report_2016.pdf

Williams, H.L. 2013. "Intellectual Property Rights and Innovation: Evidence from the Human Genome." *Journal of Political Economy* 121 (1): 1-27.

Wolfe, D.A. 2018. *Creating Digital Opportunity for Canada*. Toronto: Brookfield Institute for Innovation + Entrepreneurship and Innovation Policy Lab, Munk School of Global Affairs. https://munkschool.utoronto.ca/ipl/files/2018/04/UTMK028-Digital-Opps_V6.pdf

Wolfe, J. 2018. "U.S. Appeals Court Upholds IT, Harvard Patents on CRISPR Gene Editing." Reuters, September 10. https://www.reuters.com/article/ucberkeley-crispr/u-s-appeals-court-upholds-mit-harvard-patents-on-crispr-gene-editing-idUSL2N1VW0LC

World Intellectual Property Organization. n.d. *Industrial Property Statistics Glossary*. https://www.wipo.int/ipstats/en/statistics/glossary.html

Wright, R. 2016. "Recent Trends in Cross-Border Canada-U.S. M&A Activity." Osler, November 10. https://www.osler.com/en/resources/cross-border/2016/recent-trends-in-cross-border-canada-u-s-m-a-acti-en

Zehr, L. 2018. "QLT's Old Dilemma." *Globe and Mail*, April 23. https://www.theglobeandmail.com/report-on-business/qlts-old-dilemma/article1097054/

Institute for Research on Public Policy

Institut de recherche en politiques publiques

Founded in 1972, the Institute for Research on Public Policy is an independent, national, bilingual, not-for-profit organization. The IRPP seeks to improve public policy in Canada by generating research, providing insight and informing debate on current and emerging policy issues facing Canadians and their governments.

The Institute's independence is assured by an endowment fund, to which federal and provincial governments and the private sector contributed in the early 1970s.

Fondé en 1972, l'Institut de recherche en politiques publiques est un organisme canadien indépendant, bilingue et sans but lucratif. Sa mission consiste à améliorer les politiques publiques en produisant des recherches, en proposant de nouvelles idées et en éclairant les débats sur les grands enjeux publics auxquels font face les Canadiens et leurs gouvernements.

L'indépendance de l'Institut est assurée par un fonds de dotation établi au début des années 1970 grâce aux contributions des gouvernements fédéral et provinciaux ainsi que du secteur privé.

IRPP
1470 Peel Street, Suite 200
Montreal, Quebec H3A 1T1
Telephone: 514-985-2461
Fax: 514-985-2559
irpp@irpp.org