Centre for International
Governance Innovation

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International Mobility of Canadian Inventors and the Canadian Knowledge Economy

Olena Ivus

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Centre for International Governance Innovation

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Table of Contents

About the Author

Olena Ivus joined CIGI's Global Economy Program in April 2016, focusing on the innovation and trade research theme. Her research explores the interface between Canada's domestic innovation and international trade.

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Her work has been published in leading journals, including the *Journal of International Economics*, *Canadian Journal of Economics*, *Economic Inquiry* and the *Journal of International Business Studies*.

She received a Thomas Edison Innovation Fellowship for 2016-2017 from the Center for the Protection of Intellectual Property at George Mason University School of Law. In 2010, she won the World Trade Organization Essay Award for Young Economists.

Olena holds a Ph.D. in economics from the University of Calgary.

About the Program

Addressing limitations in the ways nations tackle shared economic challenges, the Global Economy Program at CIGI strives to inform and guide policy debates through world-leading research and sustained stakeholder engagement.

With experts from academia, national agencies, international institutions and the private sector, the Global Economy Program supports research in the following areas: management of severe sovereign debt crises; central banking and international financial regulation; China's role in the global economy; governance and policies of the Bretton Woods institutions; the Group of Twenty; global, plurilateral and regional trade agreements; and financing sustainable development. Each year, the Global Economy Program hosts, co-hosts and participates in many events worldwide, working with trusted international partners, which allows the program to disseminate policy recommendations to an international audience of policy makers.

Through its research, collaboration and publications, the Global Economy Program informs decision makers, fosters dialogue and debate on policy-relevant ideas and strengthens multilateral responses to the most pressing international governance issues.

Executive Summary

The top-level talent residing in a given country represents a key source of national innovative capacity. National governments looking to attract top talent from abroad will often turn to immigration policy reform. The literature on skilled migration establishes that immigration policy does matter in attracting and vetting highly skilled migrants, but less consideration has been paid to the factors driving innovators' migration decisions and the role played by government institutions.

The paper begins with an overview of the migratory patterns of "inventors." It examines how Canada's inventor migration patterns have changed over the years, and compares the country's performance to that of the top 15 countries of migrant destination and origin.

The analysis reveals that the count of names of Canadian native inventors residing abroad exceeds that of Canadian immigrant inventors residing in Canada. This means either that Canadian firms are bringing in fewer patenting inventors than they are losing to foreign firms, or that Canadian inventors residing abroad submit relatively more Patent Cooperation Treaty (PCT) applications, or both. Across three sectors — public research and university, corporate and individual patentees — the gap is most pronounced in the corporate sector and grows over time. Across technology fields, chemistry and electrical engineering are the most patent-intensive in Canada and also boast the largest gap in the count of inventors' names. The rate of Canadian inventor-patent emigration, as measured by the share of Canadian non-resident inventors named in Canadian PCT applications, has risen quickly over time, with the United States being the major destination country; at the same time, the Canadian inventor-patent immigration rate has been rather stable and relatively low.

The paper proceeds with the empirical analysis of the key determinants of inventor-patent emigration rates across the Organisation for Economic Co-operation and Development (OECD) countries. The rate of inventor-patent emigration over the period of 2006 to 2011 is related to the Global Competitiveness Index (GCI) in 2006-2007.

The paper concludes with a discussion of the implications of the findings and policy recommendations. The importance of building a sustainable, supportive climate for innovation is emphasized. A suitable innovation ecosystem would help Canada and Canadian firms to improve talent retention rates by providing a more attractive working environment. This conclusion is supported by the author's empirical analysis, which shows that national capacity for innovation is a key determinant of inventor-patent emigration rates across OECD countries. Furthermore, as argued in the literature, a climate for innovation would improve Canada's access to foreign knowledge and help Canada maximize its return on innovator immigration, as it stimulates technology inflows through diaspora knowledge networks and promotes international collaboration.

Introduction

The OECD (1999) once observed: "[a]lthough the pace may differ…OECD countries are moving towards a knowledge-based economy." That was in 1999. Today's knowledge economy is global in scope and competition is fiercer than ever. Firms are in an endless race to hire the best and brightest innovators, who find themselves more mobile than ever before.

The top-level talent residing in a given country represents a key source of national innovative capacity. National governments looking to attract such talent will often turn to immigration policy reform with a mind to attracting talent from abroad. For example, in recent years, many countries (including Canada, Australia and the United Kingdom) have shifted to more merit-based immigration policy.

Proactive immigration reform seems a natural response and a frontal assault on the problem. As well, the literature on skilled migration establishes that immigration policy does matter in attracting and vetting highly skilled migrants (see Hawthorne 2007). In contrast, less consideration has been paid to the factors driving innovators' migration decisions and the role played by government institutions. Key questions remain: What can governments do to attract more innovators *and* keep their retention rates high? And how can governments maximize the benefits derived from innovator migration?

To answer these questions, the paper begins with a descriptive overview of the migratory patterns of innovators, researchers, scientists, engineers, entrepreneurs and the like whose names are included in international patent applications — these groups are referred to collectively as "inventors." Focusing on the experience in Canada, the paper examines how the country's inventor migration patterns have changed over the years, and compares Canada's performance to that of the top 15 countries of migrant destination and origin. The analysis uses data gathered from international applications filed under the PCT: information on the count of inventors whose names appear in the PCT patent applications. The counts of inventors' names are weighted by innovators' innovation productivity as measured by the number of PCT patent applications associated with each inventor.

The data shows that that the count of names of Canadian native inventors residing abroad exceeds that of Canadian immigrant inventors residing in Canada. This means either that Canadian firms are bringing in fewer patenting inventors than they are losing to foreign firms, or that Canadian inventors residing abroad submit relatively more PCT applications, or both. The analysis also finds that the rate of Canadian inventor-patent emigration, as measured by the share of Canadian non-resident inventors named in Canadian PCT applications, has risen quickly over time, with the United States being the major destination country. At the same time, the Canadian inventor-patent immigration rate has been rather stable and relatively low. Trends like these are important not only for Canadian prosperity, but also for the distribution of wealth globally.

The paper then proceeds with the empirical analysis of the key determinants of inventor-patent emigration rates across the OECD countries. The rate of inventor-patent emigration over the period of 2006–2011 is related to the GCI in 2006-2007. The GCI is derived from the Executive Opinion Survey by the World Economic Forum in its *Global Competitiveness Report*. It is calculated as a weighted average of many different components (such as institutions, infrastructure, labour market efficiency, technological readiness, business sophistication and research and development [R&D] innovation), each measuring a different aspect of competitiveness. One such component is national capacity for innovation, which is isolated as a key determinant of inventor-patent emigration rates.

The paper continues with a discussion of the implications of the findings. Relying on the literature on the international migration of inventors, the potential benefit of international migration for both host and home countries is considered and the conditions under which such benefits are maximized are examined. The paper concludes with policy recommendations.

Inventor Migration Patterns

The analysis of inventor migration patterns utilizes data on migrant inventors recently collected by the World Intellectual Property Organization (WIPO) and documented in E. Miguelez and C. Fink (2013). The database provides information on the counts of inventors' names included in international applications filed in a given year under the PCT. The data also contains information on the residence and the nationality of inventors. That is, the counts are disaggregated along these three dimensions: the country/territory of origin/nationality of the inventors; the country/territory of current residence of the migrant inventors; and the year of priority filing.[1]

The data set has three key limitations, which are important to keep in mind when interpreting the results. First, the data do not allow us to observe the actual numbers of migrant inventors. Only the numbers of inventors whose names are included in patent applications abroad are observed. The numbers of inventors' names are by patent number, that is, there is no single identifier for each inventor. Second, the data set does not report the inventors' country of birth but rather their nationality, which can change over time. Last, the data is collected from the patent applications filed, without adjusting for the actual grants of the patents.

Despite the limitations mentioned above, the database offers several advantages over the alternatives. First, it covers many countries and years (241 countries/territories for each year from 1978 to 2012). Second, the residence and nationality information in the patent applications is self-reported, which arguably makes it more current and precise than assuming migration history by family name. Third, the patent applications are filed under the PCT. This allows for easier cross-country comparisons because the PCT operates worldwide in nearly all countries and implements a uniform application procedure and process.[2] Also, since the cost of filing abroad can be substantial, the underlying inventions of applications filed under the PCT system are likely to have a greater commercial significance than the inventions of applications filed domestically.[3]

Miguelez and Fink (2013) report that as many as 2,361,455 PCT applications were submitted in total by the end of 2012. This amounted to 6,112,608 of "inventor/applicant-inventor name-patent number" records, with both nationality and residence information available for 4,928,076. This implies a coverage rate of 80.6 percent on average, that is, across all countries and years. For Canada specifically, the total number of records was 112,627, with an average coverage rate of 80.95 percent. The coverage rate of applications from Canada was low prior to 2004, when many Canadians chose to defer PCT applications in favour of speedy application to the US patent office for a national patent — ensuring the earliest US filing date possible. The PCT was amended in 2004, and now provides that successful PCT application has the effect of preserving the filing date and commencing a national patent application in all member countries. With that change, the post-2004 rate of Canadian PCT applications increased.

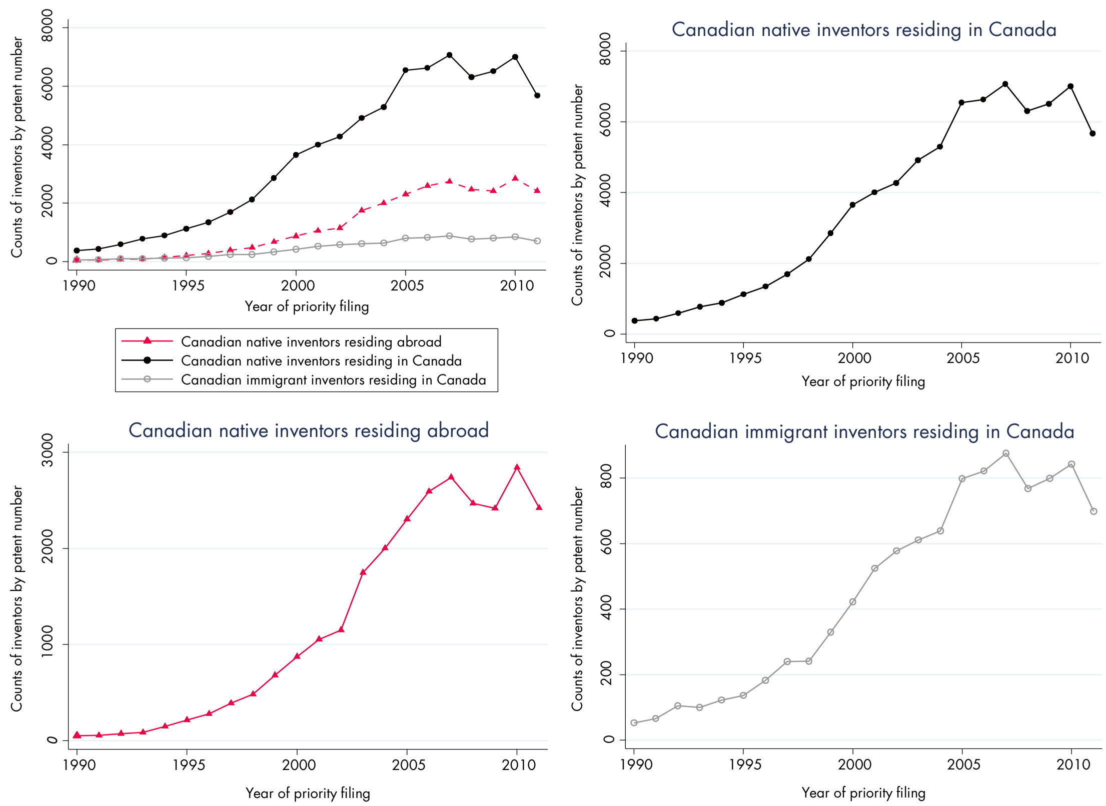
The year 2011 is the last year in the analysis, because the coverage fell across all countries in that year, dropping significantly in 2012. This reduction was the result of the United States enacting changes to its patent laws under the Leahy-Smith America Invents Act (AIA), which effectively removed the requirement that inventors also be named as applicants. The AIA was signed into law on September 16, 2011 and came into effect on September 16, 2012. PCT applicants in the United States are free to name inventors without disclosing their nationality and residence.

1 The year of priority filing is the first year of the patent application in a patent office.

2 The PCT is an international patent law treaty administered by WIPO. It assists applicants in seeking patent protection internationally for their inventions and provides a unified procedure for filing patent applications in more than one contracting state. As of June 2016, the PCT has 150 contracting states.

3 According to WIPO (2015), Canada ranked 12 in the list of countries sorted by the total number of intellectual property applications filed by applicants at a national/regional office (resident applications) or at foreign offices (applications abroad) in 2014. Among the top 20 countries, the United States, Japan and Germany filed the largest number of applications abroad (the respective numbers are 224,400, 200,000 and 105,600). Relative to the total number of applications, Canada, Israel and Switzerland have the largest share of applications filed abroad. The key factors influencing cross-border applications are proximity and market size.

Figure 1: The Counts of Inventors by Patent Number in PCT Applications from Canada



Data source: Author's own calculations using data from Miguelez and Fink (2013).

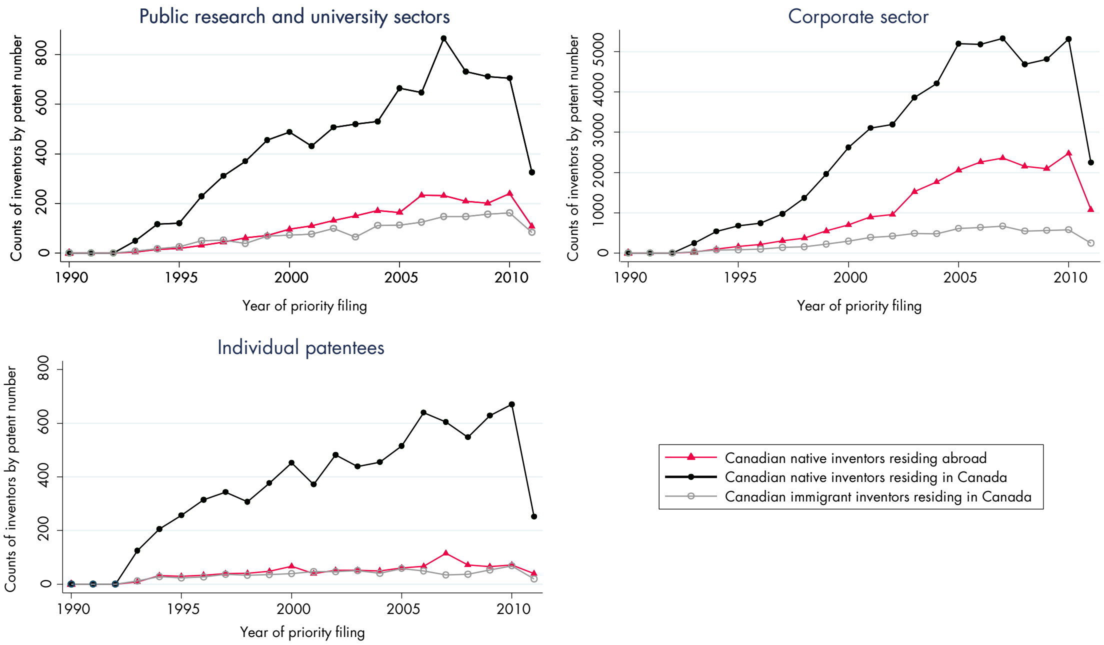
Figure 1 plots the counts of inventors' names by patent number included in PCT applications filed by Canadian applicants in each year from 1990 to 2011. Three groups of Canadian inventors are considered: native inventors residing in Canada; native inventors residing abroad; and immigrant inventors residing in Canada. It is apparent that across the three groups of inventors, Canadian native inventors residing in Canada filed the most PCT applications in each year, followed by Canadian native inventors residing abroad. The count of native inventors residing in Canada has been steadily rising since 1990, peaking at 7,072 in 2007. The count fell in 2008-2009, but recovered almost fully (rising to 7,004) in 2010. A similar pattern is observed for the other two groups — except that for Canadian inventors residing abroad, the year 2010 was the strongest. The 2010 count exceeded the 2007 count, despite the 2008-2009 decline.

Figures 2 and 3 provide data about the number of inventors in PCT applications from Canada.

Figure 2 focuses on application type and breaks down the data into three sectors: public research and university; corporate; and individual patentees.[4] The analysis reveals two key differences across these sectors. First, since 2007, the public research and university sector has suffered a steady decline of native inventors residing in Canada, while in the corporate sector, the count in 2010 exceeded that in 2007. Second, the disparity between Canadian native inventors residing abroad and immigrant inventors residing in Canada varies noticeably across sectors. This gap is most pronounced in the corporate sector, where it is positive in all years (that is, Canadian native inventors residing abroad submit relatively more PCT applications each year) and only grows with time. This differs dramatically from the individual patentees' sector, where the difference is minimal and fluctuates both ways over time.

4 For some patents, sectors were not identified.

Figure 2: The Counts of Inventors by Patent Number in PCT Applications from Canada, by Sector



Data source: Author's own calculations using data from Miguelez and Fink (2013).

Figure 3 breaks down the data into five technology fields: electrical engineering; instruments; chemistry; mechanical engineering; and other fields. Across the five technology fields, chemistry and electrical engineering are the most patent-intensive in Canada, as evidenced by the systematically larger number of PCT applications from Canadian inventors in these two fields. The data further show that the count of Canadian native inventors residing in Canada has steadily fallen since 2007 in chemistry, but mostly risen (with the exception of 1994-1995, 2008 and 2011) in mechanical engineering. The gap in the count between Canadian native inventors residing abroad and Canadian immigrant inventors residing in Canada is most pronounced in chemistry.

To deepen our understanding of the migratory patterns of Canadian inventors, inventor-patent immigration and emigration rates are calculated. The rate of inventor-patent immigration in year *t* is given by the (percent) share of inventor names in Canadian PCT patent applications with migratory background, calculated for that year as follows:

$$Inventor - patent\ immigration\ rate_t = \frac{Immigrants_t}{Residents_t} \times 100$$

where $Immigrants_t$ is the number of immigrant inventors residing in Canada in year *t* and $Residents_t$ is the number of Canadian resident inventors (both native and immigrant inventors) in year *t*.

The rate of inventor-patent emigration in year *t* is the (percent) share of Canadian non-resident inventors in Canadian PCT applications, calculated for that year as follows:

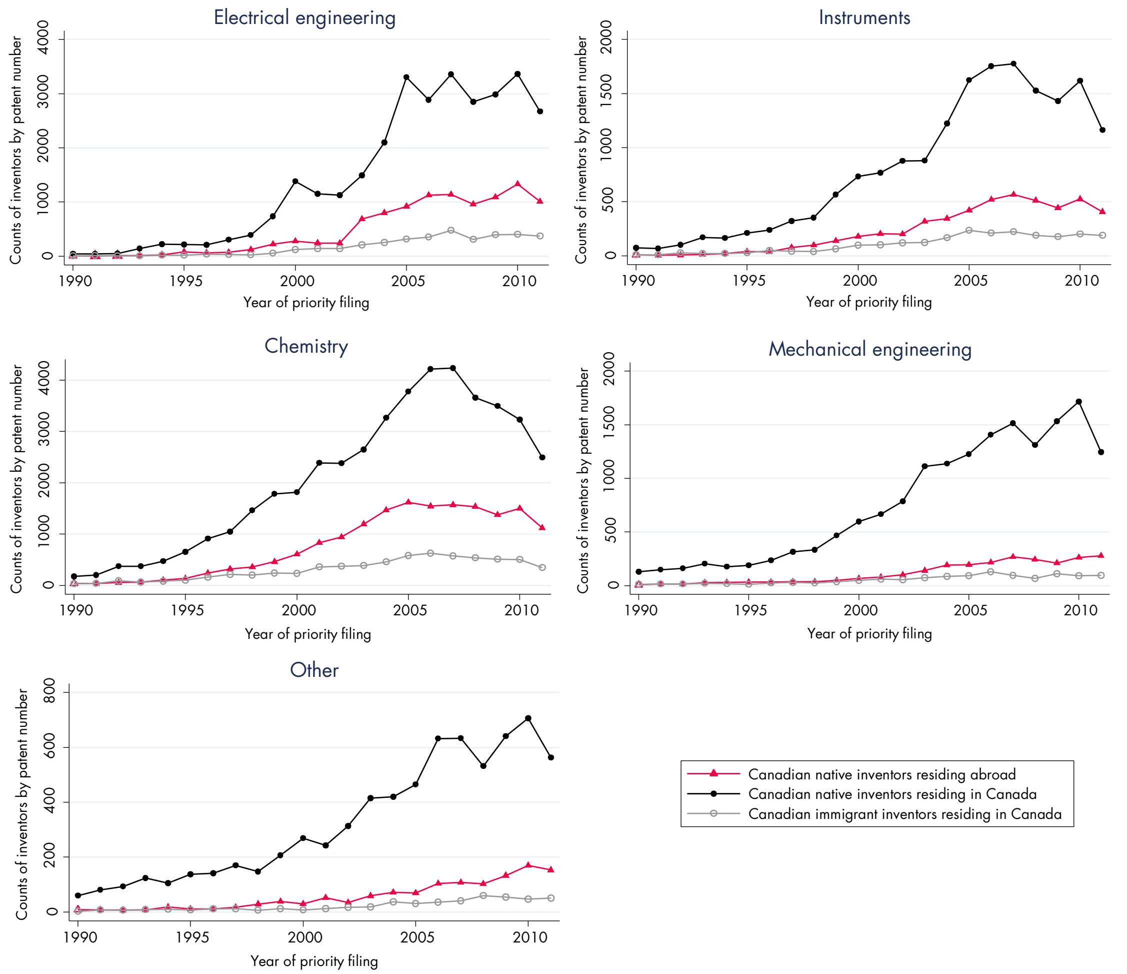
$$Inventor - patent\ emigration\ rate_t = \frac{Emigrants_t}{Residents_t + Emigrants_t} \times 100$$

where $Emigrants_t$ is the number of Canadian inventors that are residing abroad in year *t*.

It is important to emphasize that the numbers of inventors' names are by patent number (that is, the data does not have a single identifier for each inventor). Thus, the inventor-patent migration rates also reflect the productivity of inventors in terms of the number of patents filed.

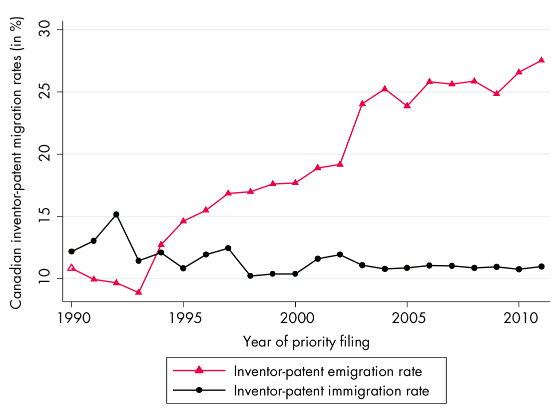
Figure 4 plots the two rates over time. The results are striking. We see that the rate of inventor-patent emigration first exceeded the rate of inventor-patent immigration in 1994, and the two rates have been steadily diverging since then. Regressing each rate on the time count variable, we find that over the period from 1990 to 2011, the inventor-patent emigration rate has been rising by 0.93 percentage points per year on average, while the inventor-patent immigration rate has been falling by

Figure 3: The Counts of Inventors by Patent Number in PCT Applications from Canada, by Technology Field



Data source: Author's own calculations using data from Miguelez and Fink (2013).

Figure 4: Inventor-Patent Immigration and Emigration Rates in Canada



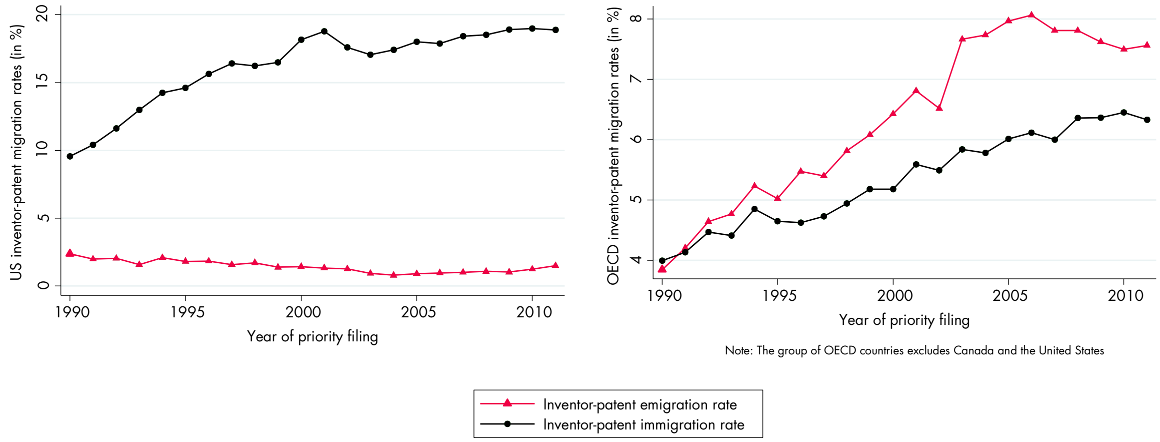
Data source: Author's own calculations using data from Miguelez and Fink (2013).

0.10 percentage points per year on average. The estimates are statistically significant at the one percent level. When the data is limited to the period of 2000–2011, we find that the inventor-patent emigration rate has been rising by 0.80 percentage points per year on average, and this estimate is also highly statistically significant. At the same time, the inventor-patent immigration rate did not change on average; the estimate of the average annual change in the inventor-patent immigration rate is not statistically different from zero.[5]

It is instructive to compare the rates of inventor-patent immigration and emigration in Canada with those of the United States and other OECD

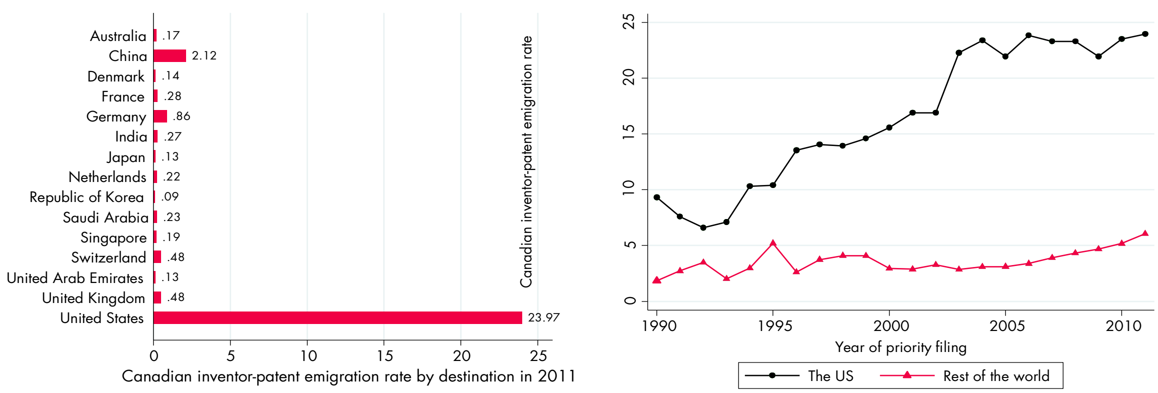
5 In all regressions, standard errors are robust to heteroscedasticity of unknown form.

Figure 5: Inventor-Patent Immigration and Emigration Rates in the United States (on the left) and OECD Countries (on the right)



Data source: Author's own calculations using data from Miguelez and Fink (2013).

Figure 6: Canadian Inventor-Patent Emigration Rate by the Country of Destination



Data source: Author's own calculations using data from Miguelez and Fink (2013).

countries. Figure 5 shows the results, with the US rates on the left and the OECD countries' rates on the right. The group of OECD countries excludes Canada and the United States. The differences with Canada are clearly visible. The United States stands out, in that the rate of inventor-patent immigration exceeded the inventor-patent emigration rate in each year from 1990 to 2011. The US inventor-patent emigration rate was relatively low in 1990 (2.4 percent, compared to 10.8 percent in Canada), and it has been falling ever since, by 0.06 percentage points per year on average.[6] Meanwhile, the US inventor-patent immigration rate has continually risen, by 0.39 percentage points per year on average. As for the other OECD countries, the inventor-patent emigration rate exceeded the inventor-patent immigration rate in all years after 1991, which is similar to Canada. However, unlike in Canada, the inventor-patent immigration rate has been rising since 1990, by 0.12 percentage points per year on average. The rate of inventor-patent emigration has also been rising, although not as fast as in Canada (by 0.20 percentage points per year versus 0.93 percentage points in Canada).

To further explore the cross country variation in the migration data, the rate of Canadian inventor-patent emigration is examined by the destination country. Figure 6 summarizes the findings. The figure on the left reports inventor-patent emigration rates for the top 15 destination countries

6 Unless explicitly stated, all estimates of the average annual change are statistically significant at the one percent level.

Figure 7: Canadian Inventor-Patent Immigration Rate by the Country of Origin

Data source: Author's own calculations using data from Miguelez and Fink (2013).

in 2011. The rate of inventor-patent emigration into the United States was by far the highest, at 23.97 percent, followed by China (2.12 percent) and Germany (0.86 percent). The figure on the right plots the rates of inventor-patent emigration into the United States and the rest of the world over time. It shows that both rates have been steadily rising, but the rate of inventor-patent emigration into the United States has risen faster (0.92 versus 0.10 percentage points per year on average).

In Figure 7, the rates of Canadian inventor-patent immigration by the country of origin are summarized. The figure on the left reports inventor-patent immigration rates for the top 15 source countries in 2011. The rate of inventor-patent immigration from the United States was the highest, at 2.06 percent, with the other countries not far behind. The United States is followed by China (1.21 percent) and the United Kingdom (0.78 percent). The figure on the right further shows that the rate of Canadian inventor-patent immigration from the United States was relatively low, equal to 2.47 percent on average. Also, it is rather stable over time; the estimate of the average annual change is not statistically different from zero. The rate of Canadian inventor-patent immigration from the rest of the world exceeds that from the United States and shows only a slight decline over time.[7]

To summarize, the analysis of international patent applications filed under the PCT reveals that the count of names of Canadian native inventors residing abroad (weighted by the number of applications filed) exceeds that of Canadian immigrant inventors residing in Canada. This gap is particularly striking in the corporate sector. The count is by application number, and so there are two plausible reasons for the result. First, it could be that Canadian firms are bringing in fewer patenting inventors than they are losing to foreign firms. In other words, the group of Canadian native inventors residing abroad is simply larger, and this difference is driving the result. Second, it could be that Canadian native inventors residing abroad have higher innovation productivity on average (innovation productivity being measured by the number of patents associated with that inventor). Across technology fields, chemistry and electrical engineering are most patent-intensive in Canada and also boast the largest gap in the count of inventors' names across the two migratory groups. Again, Canadian native inventors residing abroad submit relatively more PCT applications. The Canadian inventor-patent emigration rate, as measured by the share of Canadian non-resident inventors in Canadian PCT applications, has risen quickly over time, with the United States being the major destination country. At the same time, the Canadian inventor-patent immigration rate has been rather stable and relatively low.

7 The rate of Canadian inventor immigration from the rest of the world is falling by 0.05 percentage points per year on average. The estimate is statistically significant at the five percent level.

Determinants of Inventor-Patent Emigration Rates

The inventor migration patterns described above are alarming and suggest that immigration policy alone cannot be relied upon for retaining talent. This begs the question: what can Canada do to attract more innovators *and* keep them? To answer this question, we need to understand the key determinants of inventor-patent emigration rates. This is explored next for a sample of 33 OECD countries.

Specifically, the rates of inventor-patent emigration across the OECD countries are related to the GCI. The outcome variable is the inventor-patent emigration rate for the country of origin/nationality of the inventors *i* over the period of 2006–2011. It is calculated for each country *i* as the (percent) share of *i*'s non-resident inventors in *i*'s PCT patent applications over the years from 2006 to 2011. The independent variable is the GCI for 2006-2007, as it aims to control for initial or predetermined characteristics of country *i* that may affect inventors' emigration. Of particular interest is the capacity for innovation component, and it is included as a separate control in order to isolate its individual impact. Data on both the scores a country received on each of these indicators (that is, the GCI and the capacity for innovation component) as well as the country's ranking relative to the other countries surveyed is used.[8]

Figure 8 plots the inventor-patent emigration rate over the 2006–2011 period and the GCI in 2006-2007 for the OECD countries, where the GCI is measured in terms of value on the left and rank on the right. It is apparent that the relationship between the inventor-patent emigration rate and the GCI value is negative; the coefficient of correlation equals -0.64 and is highly statistically significant. At the same time, the relationship between the inventor-patent emigration rate and the GCI index rank is positive; the coefficient of correlation equals 0.55 and is highly statistically significant. Thus, regardless of how the GCI is measured, the rate of inventor-patent emigration is found to be high in OECD countries with low global competitiveness.

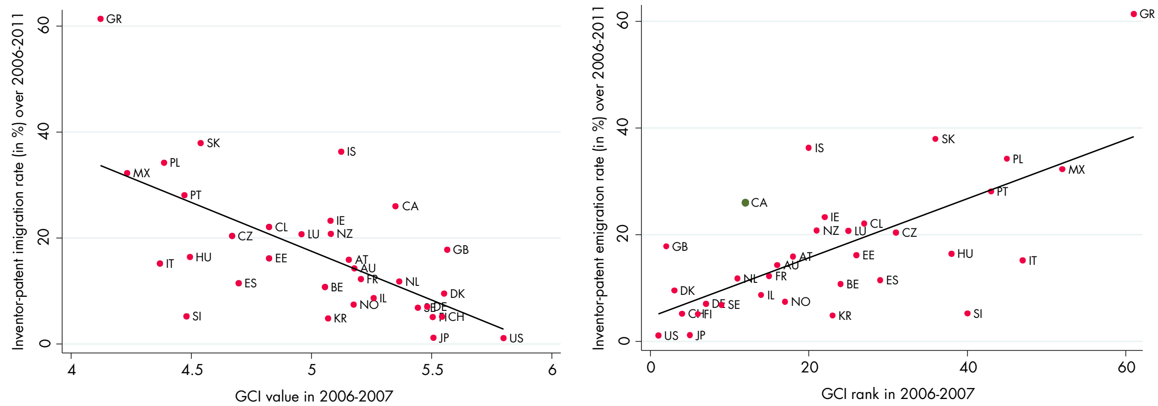
Table 1 shows the cross-sectional regression results. The results are presented in six columns. In columns (1) and (2), the inventor-patent emigration rate over the 2006–2011 period on the GCI value and the GCI rank, respectively, is regressed. In columns (3) and (4) in Table 1, the capacity for innovation component is used as an alternative independent variable. Last, in columns (5) and (6), both the GCI and capacity for innovation are controlled for in order to compare their individual impacts.

It is apparent from Table 1 that the coefficient on the GCI is negative and highly statistically significant in column (1) and positive and highly statistically significant in column (2), which is in line with the results in Figure 8. Of note, the coefficient of determination (R^2) equals 0.415 in column (1) and 0.459 in column (2), meaning that country differences in their GCI (in addition to the constant) explain from 41.5 to 45.9 percent of cross-country variation in the inventor-patent emigration rate. These results suggest that the GCI is a relevant determinant of the inventor-patent emigration rate. Likewise, it follows from columns (3) and (4) that capacity for innovation is a relevant determinant of the inventor-patent emigration rate. The coefficient on capacity for innovation is negative and highly statistically significant in column (3) and positive and highly statistically significant in column (4). These results imply that the inventor-patent emigration rate is high in OECD countries with low innovation capacity. Across the two independent variables, capacity for innovation has a higher explanatory power. It explains as much as 54.6 or 61.4 percent of cross-country variation in the inventor-patent emigration rate. The results in columns (5) and (6) further show that when both independent variables are controlled for in one regression, the coefficient on capacity for innovation remains highly statistically significant while the coefficient on the GCI becomes statistically insignificant.

The above findings are important as they suggest that a country's innovation capacity is a key determinant of its inventor-patent emigration rate. Once capacity to innovate is controlled for, the other indicators of global competitiveness taken together have no statistically significant impact. Across the OECD countries, countries with lower innovative capacity have a higher inventor-patent emigration rate. It is important to keep in mind that the inventor-patent emigration rate was calculated using the data on the numbers

8 The survey asked respondents to evaluate on a scale of 1 (the worst possible situation) to 7 (the best possible situation) individual indicators of global competitiveness.

Figure 8: Inventor-Patent Emigration Rates and the GCI value (on the left) and Rank (on the right) by the Country of Origin



AT	Austria	FI	Finland	LU	Luxembourg
AU	Australia	FR	France	MX	Mexico
BE	Belgium	GB	United Kingdom	NL	Netherlands
CA	Canada	GR	Greece	NO	Norway
CH	Switzerland	HU	Hungary	NZ	New Zealand
CL	Chile	IE	Ireland	PL	Poland
CZ	Czech Republic	IL	Israel	PT	Portugal
DE	Germany	IS	Iceland	SE	Sweden
DK	Denmark	IT	Italy	SI	Slovenia
EE	Estonia	JP	Japan	SK	Slovakia
ES	Spain	KR	Republic of Korea	US	United States

Data source: Author's own calculations using data from Miguelez and Fink (2013).

Table 1: The Determinants of the Inventor-Patent Emigration Rate

Variables	Value	Rank	Value	Rank	Value	Rank
	(1)	(2)	(3)	(4)	(5)	(6)
GCI	-18.439***	0.554***			-2.390	0.056
	(5.129)	(0.147)			(6.776)	(0.158)
Capacity for innovation			-10.435***	0.593***	-9.446***	0.549***
			(2.093)	0.100	(3.031)	(0.152)
Constant	109.698***	4.600	66.904***	4.145*	102.431***	3.829
	26.765	2.863	(10.999)	(2.055)	25.661	2.328
R^2	0.415	0.459	0.546	0.614	0.548	0.616
Observations	33	33	33	33	33	33

Notes: Ordinary Least Squares estimation. ***, **, and * denote 1%, 5% and 10% significance level. Robust standard errors are in parentheses.

of inventors by patents. As such, the negative association could be the result of two factors. First, it could be driven by the number of inventors, in which case the negative association would imply that countries with low innovative capacity fail to attract and retain inventors. But the number of international patent applications could also play a role, as it could be that among countries with lower innovative capacity, nationals residing abroad file relatively more international patent applications than nationals residing at home. This would arise if, for example, it is nationals with the highest innovation productivity that choose to reside abroad when their home country's innovation is low. Further research is needed to evaluate the relative importance of these factors.

Implications of Innovator Migration

The implications of innovator migration have been studied extensively. For host countries, the literature emphasizes that high-skilled migration provides an important contribution to innovation. For example, while foreign-born individuals made up only 12 percent of the US population in 2000 (Hunt and Gauthier-Loiselle 2010), such immigrants accounted for 26 percent of the US-based Nobel Prize winners between 1990 and 2000 (Brunello, Garibaldi and Wasme 2007). They also were responsible for starting 25 percent of US public venture-backed companies between 1990 and 2005 — with most of these start-ups being in sectors where the rates of innovation are the highest, including the high-technology manufacturing, information and life sciences sectors (Anderson and Platzer 2006). Immigrant college graduates in the United States patent about twice as much as their US-born counterparts (Hunt and Gauthier-Loiselle 2010).

Canada has experienced similar trends. While foreign-born individuals made up 20 percent of Canada's population in 2000, at least 35 percent of all Canada Research Chairs (arguably the most efficacious research talent) are foreign born (Downie 2010). J. Partridge and H. Furtan (2008) studied the contribution of skilled immigrants to Canadian innovation, as measured by international (US) patents and the number of publications to scientific journals. The analysis utilizes annual data at the provincial level (seven provinces) over the period from 1995 to 2005. The authors found that skilled immigrants have a positive and significant impact on innovation flows in their home province. This impact is particularly large for skilled immigrants coming into Canada from developed countries. More recently, J. Blit, M. Skuterud and I. J. Zhang (2016) examined the effect of skilled immigration between 1981 and 2006 on patents per capita granted to inventors across 98 Canadian cities. Following the methodology in J. Hunt and M. Gauthier-Loiselle (2010), the paper finds relatively modest effects of skilled immigration on innovation, which the authors attribute to the relatively low employment rates of Canadian immigrants in science, technology, engineering and mathematics (often referred to as STEM) jobs.

High-skilled migration can also contribute to the innovative capacities of originating/sending countries, although evidence of this effect is more limited. K. Mayr and G. Peri (2009) and C. Dustmann, I. Fadlon and Y. Weiss (2011) provide evidence that when migrants acquire skills and innovative ideas abroad, they share this knowledge upon returning home — typically through cross-border diaspora networks and close-knit, ethnic scientific communities. According to A. Agrawal et al. (2011), the emigration of inventors weakens local knowledge networks but creates diaspora knowledge networks that improve the remaining innovators' access to foreign knowledge. The authors find that the diaspora effect on knowledge flows — also referred to as the "brain bank" effect — is particularly strong in India. W. R. Kerr (2008) explores whether ethnic scientific and entrepreneurial communities in the United States facilitate technology transfer to foreign countries of the same ethnicity. The findings suggest that ethnicity plays an important role in foreign technology transfer and is particularly strong in high-tech industries and Chinese communities. A. Saxenian (2002) and Saxenian, Y. Motoyama and X. Quan (2002) provide evidence on Silicon Valley's ethnic networks. Saxenian, Motoyama and Quan (2002, 25) report that 82 percent of Chinese and Indian immigrant scientists and engineers "share information about technology with colleagues in their native countries (and 28 percent do so on a regular basis)." More recently, A. Naghavi and C. Strozzi (2015) show that knowledge acquired by emigrants tends to flow back into their country of origin through diaspora networks, but only to the extent that there is enough absorptive capacity in the origin county.

O. Ivus and A. Naghavi (2014) find a positive association between inventor emigration rates and the degree of international collaboration based on published PCT applications. The rate of inventor emigration is calculated from Miguelez and Fink's (2013) data, as defined above, over the period from 2001 to 2011. The degree of international collaboration is calculated for the year 2011 as the ratio of the number of a country's inventors in foreign-owned PCT applications (submitted by foreign firms for patenting in that country) to the number of a country's inventors in all PCT applications. The data for this measure is taken from section A.6.2. of the WIPO World Intellectual Property Indicators (WIPO 2012). The analysis is performed on 70 countries with the highest number of inventors in all PCT applications. The results show that a one percentage point increase in the rate of inventor emigration is associated with a one percentage point increase in the share of inventors in foreign-owned PCT applications.[9] Simply put, cross-border collaboration on PCT applications is high in countries with high inventor emigration rates. In Canada, for example, the inventor emigration rate was 25 percent over the period of 2001–2011, with as many as 23,737 inventors residing abroad and 72,183 inventors residing in Canada over this period. Around 49 percent of Canadian inventors (4,140 out of the total of 8,398) were included in foreign PCT applications in 2011. In Switzerland, by contrast, the rate of inventor emigration and the share of inventors in foreign-owned PCT applications were five percent and 28 percent, respectively. Ivus and Naghavi conclude that a positive link between inventor emigration rates and the degree of international collaboration could be the result of inventor migration promoting international knowledge circulation and technology diffusion through diaspora knowledge networks.

Policy Recommendations

For many countries that have experienced emigration of top talent, the flight of high-skilled human capital is counted as a loss and a trend to be discouraged through more restrictive mobility policies. However, obstructing mobility to prevent brain drain has proven ineffective. In fact, most attempts to control and manage skilled emigration by prohibition and taxation have failed (Lowell 2001). Restrictions on talent mobility also prevent a country from reaping gains from migration that could arise, for example, when high-skilled expatriates transfer knowledge attained abroad to their home countries. J. Bhagwati (2003) argues that source countries' policies should focus on organizing diaspora networks, and that this strategy is much more likely to succeed today than a retention policy.

Likewise, for countries looking to attract talented immigrants, the knee-jerk response is nearly always to reform immigration laws. While immigration policy matters for selecting and attracting high-skilled migrants (see, for example, Hawthorne 2007), it cannot be relied upon for retaining talent. In order to retain top talent and maximize the benefits derived from innovator migration, reforms of immigration policy should be accompanied by institutional reforms aimed at building and sustaining a climate supportive of innovation.

For Canada, overhauling some of its regulatory processes is one avenue to pursue. Wherever Canada's regulations and barriers to market entry are more burdensome than other advanced countries, policy makers would be wise to reduce red tape for new innovators to encourage local development and market entry. According to the data documented in the 2015-2016 Global Competitiveness Report, Canada ranks thirteenth (out of 140 countries) in global competitiveness.[10] Canada's position has improved by two points from the previous year, but is still low. The five most problematic factors for doing business in Canada are: insufficient capacity to innovate; lack of access to financing; inefficient government bureaucracy; tax rates; and complexity of tax regulations.[11]

The author's findings further suggest that the reform of the innovation ecosystem is a particularly important avenue to pursue for Canada. National capacity to innovate is a key determinant of the inventor-patent emigration rate, and it is low in Canada. Canada ranked twenty-fourth in the "innovation and [business] sophistication factors" component of the GCI index. The 2015-2016 Global Competitiveness Report concludes that "Canada should continue to foster innovation at the company level. Company spending on R&D (26th) and capacity to innovate (23nd) are significantly below levels in the United States" (World Economic Forum 2015, 25).[12] For comparison, Switzerland tops the ranking and also "leads the innovation pillar, thanks to its world-class research institutions (1st), high spending on research and development (R&D) by companies (1st), and strong cooperation between the academic world and

9 The estimate is statistically significant at the one percent level.

10 Competitiveness is defined as "the set of institutions, policies, and factors that determine the level of productivity of a country" (World Economic Forum 2015, 35).

11 These data are derived from the World Economic Forum's Executive Opinion Survey 2015, which captured the opinions of over 14,000 business leaders in 144 economies between February and June 2015.

12 Among Canada's strengths are: highly efficient labor markets (seventh); good outcomes in health and primary education (seventh); and a solid institutional environment (sixteenth), in particular for private institutions (eighth).

the private sector (3rd)" (ibid., 23). The United States is ranked third: "The United States' major strength is its unique combination of exceptional innovation capacity (4th), large market size (2nd), and sophisticated businesses (4th). The country's innovation capacity is driven by collaboration between firms and universities (2nd), human capital (4th on availability of scientists and engineers), and company spending on R&D (3rd)" (ibid., 24).

One way of building an environment conducive to innovative activity is through the regulation and reform of intellectual property rights (IPRs). Consider that the underlying purpose of IPR protection is to encourage progress and innovation by securing a financial return on inventions (Maskus 2012). IPRs are designed to foster innovation by protecting innovators' intellectual assets, and given that innovators are the producers of intellectual property, IPR protection has a central role to play in knowledge circulation and the maximization of intellectual property gains from innovator migration.[13] There is room for improvement for Canada here as well. L. A. Hall and S. Bagchi-Sen (2002) studied the relationships among R&D intensity, innovation measures and business performance in the Canadian biotechnology industry, and found that the Canadian patent process has been characterized as one of the greatest barriers to innovation.[14] Reducing the costs of intellectual property protection would encourage Canada's innovation-intensive sectors and give firms in those sectors an edge in recruiting international talent.

Conclusion

The analysis of international patent application data reveals that Canada's rate of inventor-patent emigration (given by the share of Canadian non-resident inventors in Canadian PCT applications) has been falling relative to Canada's inventor-patent immigration rate (given by the share of inventor names in Canadian PCT applications with migratory background) since the year 1994. Whether this divergence is primarily driven by inventors' migration patterns or their patenting decisions, the findings carry important implications for Canadian prosperity. To reverse this trend, Canadian policy makers must consider how to attract more innovators to Canada and keep them here. While reform of immigration policy is the typical "go-to" method to attempt this, policy makers often overlook the importance of building and sustaining a supportive climate for innovation. A suitable innovation ecosystem would help Canada and Canadian firms to improve talent retention rates, by providing a more attractive working environment. This conclusion is supported by the author's empirical analysis, which shows that national capacity for innovation is a key determinant of inventor-patent emigration rates across the OECD countries. Furthermore, as argued in the literature and discussed in this paper, a climate for innovation would improve Canada's access to foreign knowledge and help Canada maximize its return on innovator immigration, as it stimulates technology inflows through diaspora knowledge networks and promotes international collaboration.

13 This conclusion is supported by the findings in Naghavi and Strozzi (2015), which show that innovator emigration generates brain gain from diaspora networks for source countries as long as the source countries provide adequate protection for intellectual property.

14 Other great barriers to innovation are: Canadian government regulations; lack of government research funds; and lack of skilled managers and skilled researchers (Hall and Bagchi-Sen 2002).

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