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STUDY ON INTELLECTUAL PROPERTY AND BRAIN DRAIN - A MAPPING EXERCISE

prepared by the Secretariat and peer-reviewed by Prof. Francesco Lissoni, GREThA Université Bordeaux IV

1. The Annex to this document contains a Mapping Exercise undertaken in the context of the Project on Intellectual Property (IP) and Brain Drain (CDIP/7/4/Rev.) approved by the Committee on Development and Intellectual Property (CDIP) in its Seventh Session, held in May 2011. The study describes the mobility patterns of knowledge workers over the 1991-2010 period using information on inventor nationality and residence in the Patent Cooperation Treaty (PCT) applications.

2. The CDIP is invited to take note of the information contained in the Annex to this document.

[Annex follows]

EXECUTIVE SUMMARY

Introduction

The international mobility of skilled workers and its economic implications have emerged as important development topics. The project on intellectual property (IP) and brain drain seeks to generate new insights into this topic by exploring the potential of patent data to cast light on a specific category of highly skilled migrants – namely inventors. In particular, by exploiting information on inventor nationality and residence in Patent Cooperation Treaty (PCT) applications, it maps the migration of scientists and engineers, thereby establishing a partial geography of high-skilled migration. The present document describes in detail the mobility patterns of inventors over the 1991-2010 period. The underlying analysis is entirely descriptive and, by itself, does not offer evidence on the causes and consequences of skilled migration.

Main concepts

International migration can be defined as "movements of persons who leave their country of origin, or the country of habitual residence, to establish themselves either permanently or temporarily in another country" (IOM, *2008*, pp. 495).[1] In particular, the *international mobility of skilled individuals* is defined as the cross-border mobility of persons who earned, "either by tertiary level of education or occupational experience, the level of qualifications typically needed to practice a (highly-skilled) profession" (Op. Cit., pp. 494).

The term *brain drain* is defined as the "emigration of trained and talented persons from the country of origin to another country resulting in a depletion of skills resources in the former" (Op. Cit., pp. 492). Different from other international factor flows, the term 'brain drain' implies that net flows of talented people are heavily unbalanced in one direction (Salt 1997).[2]

This phenomenon has the potential to seriously affect sending countries, often developing economies. In particular, the exit of skilled workers directly reduces an economy's human capital endowment. Reduced prospects for economic development are the inevitable consequence. In the longer term, the possibility of return migration – and the associated "brain gain" – and the economic contributions of overseas diasporas may attenuate initial brain drain losses or may even lead skilled migration to be socially beneficial. However, the longer term effects of skilled worker migration remain an empirical question.

Population censuses are the most used source of information

Advances in our understanding of the effects of skilled worker migration have to a significant extent been due to new data becoming available over the last 15 years. These data consist of information on migrants by destination country based on population censuses.

One can define the emigration rate of a given country *i* as the share of country *i*'s native population residing abroad relative to country *i*'s total native population. Similarly, the emigration rate of skilled people, or the 'brain drain' rate, is computed as the tertiary educated nationals living abroad over the tertiary educated population residing at home.

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[1] IOM. 2008. "World Migration 2008: Managing Labour Mobility in the Evolving Global Economy." Geneva, Switzerland: International Organization for Migration.
[2] Salt, John. 1997. "International Movements of the Highly Skilled". OECD Social, Employment and Migration Working Paper 3. OECD Publishing.

The global emigration rate was estimated to be around 2.4 percent in 2000 – as extracted from census data. In all regions, the emigration rate for the tertiary educated is significantly higher than the total emigration rate. The global emigration rate of high-skilled persons from Africa, estimated at 10.6 percent, is notoriously high, especially when compared to other regions of origin and the world average of 5.4 percent. The Latin America and the Caribbean (LAC) region also shows a relatively high emigration rate for high-skilled persons (8.8 percent). Meanwhile, the brain drain rate in North America stood at only 1.38 percent.

Census-based datasets have certain limitations

Notwithstanding their value for economic research, census-based datasets have certain limitations. For instance, migrant stock datasets typically cover only a single year, or two at the most. Moreover, the data are only released every 10 years – 2010 census data have not even been released to the general public yet!

In addition, the majority of the existing datasets provides a skills breakdown according to three schooling levels, which only offers a rough differentiation of skills. In particular, tertiary education may include non-university tertiary degrees, undergraduate university degrees, postgraduate degrees and doctoral degrees. The economic effects of migration in the sending and host countries will likely vary across different types of tertiary educated individuals.

Focusing on inventor migration

Focusing on inventor migration as captured in patent applications, as this report does, can overcome many of the limitations associated with census-based data. It captures one specific class of highly skilled workers that is bound to be more homogenous than the group of tertiary educated workers as a whole. In addition, inventors arguably have special economic importance, as they create knowledge that is at the genesis of technological and industrial transformation.

PCT applications have the unique characteristic that, in the majority of cases, they record both the residence and the nationality of the applicants. This has to do with the requirement under the PCT that only nationals or residents of a PCT contracting state can file PCT applications. To verify that applicants meet at least one of the two eligibility criteria, the PCT application form asks for both nationality and residence.

At the same time, it turns out that, until 2012, US patent application procedures required all inventors in PCT applications to be also listed as applicants. Thus, if a given PCT application included the US as a country in which the applicant considered pursuing a patent – a so-called designated state in the application – all inventors were listed as applicants and ensured that their residence and nationality information were available. Indeed, this is the case for the majority of PCT applications, reflecting the popularity of the US as the world's largest market.

As a result, nationality and residence information are available for 80.6 percent of the inventors. More specifically, PCT records offer good coverage of inventor nationality and residence information for all countries between 2004 and 2011. Before 2004 it is high for most countries except Canada, the Netherlands, and the US. Unfortunately, as an unintended consequence of US patent reform, the coverage of inventor nationality and residence information in PCT records declined sharply starting in September 2012.

Inventors are highly mobile

PCT records point to exceptionally high migration rates for inventors – estimated at 7.46 percent for the 10-year time window between 1991 and 2000, and at 9.95 percent for the 2001-2010 window. By comparison, census data suggests a 5.4 percent migration rate for the population with tertiary education. Thus, inventors are more mobile than skilled workers in general, which already are more mobile than the general population.

For the 2001-2010 period, North America as well as Oceania and the Pacific show the largest inventor immigration rates with, respectively, 17.76 and 12.07 percent. The inventor immigration rate in countries of the Organization for Economic Co-operation and Development (OECD) stands at 10.26 percent – higher than for non-OECD countries (6.13 percent). High income economies – according to the World Bank 2012 classification – also show, on average, large immigration rates during 2001-2010 (10.47%) as compared to upper and lower middle income economies (3.39% and 2.04%, respectively).

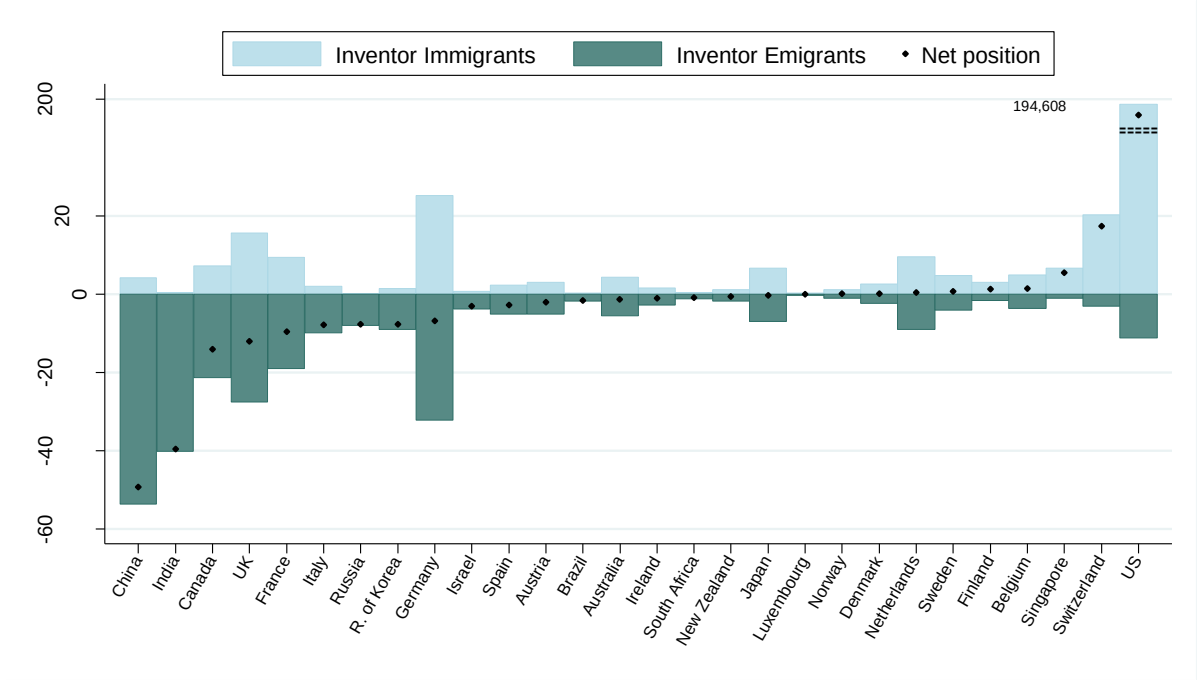
Immigrant inventors are highly concentrated in Europe and North America

During the 2001-2010 period, 95.34 percent of immigrant inventors resided in an OECD country, and 97.7 percent of them lived in a high income economy. North America contributes the most to these figures: 59.30 percent of immigrant inventors resided in North America. In addition, 31.87 percent of them lived in Europe.

At the country level, for the 2001-2010 period, the United States (US) hosted the large majority of immigrant inventors, accounting for 57.17 percent of them. After the US, other countries with large inventor immigrant stocks include Germany (7.44%), Switzerland (6.00%), and the United Kingdom (UK) (4.63%). When looking at the geographical distribution of immigrants from non-high income countries, the US stands out as by far the largest destination country (74.87%), indicating that the US is especially appealing for migrant inventors from low and middle income countries.

Moreover, there are fifteen times as many immigrant inventors in the US as there are US inventors residing abroad – Figure E.1. Interestingly, despite considerable inflows of inventors, Germany and the UK see more inventors emigrating than immigrating. Canada and France similarly show a negative net inventor immigration position.

Figure E.1: Immigrant and emigrant inventors (in thousands) and net migration position, 2001-2010



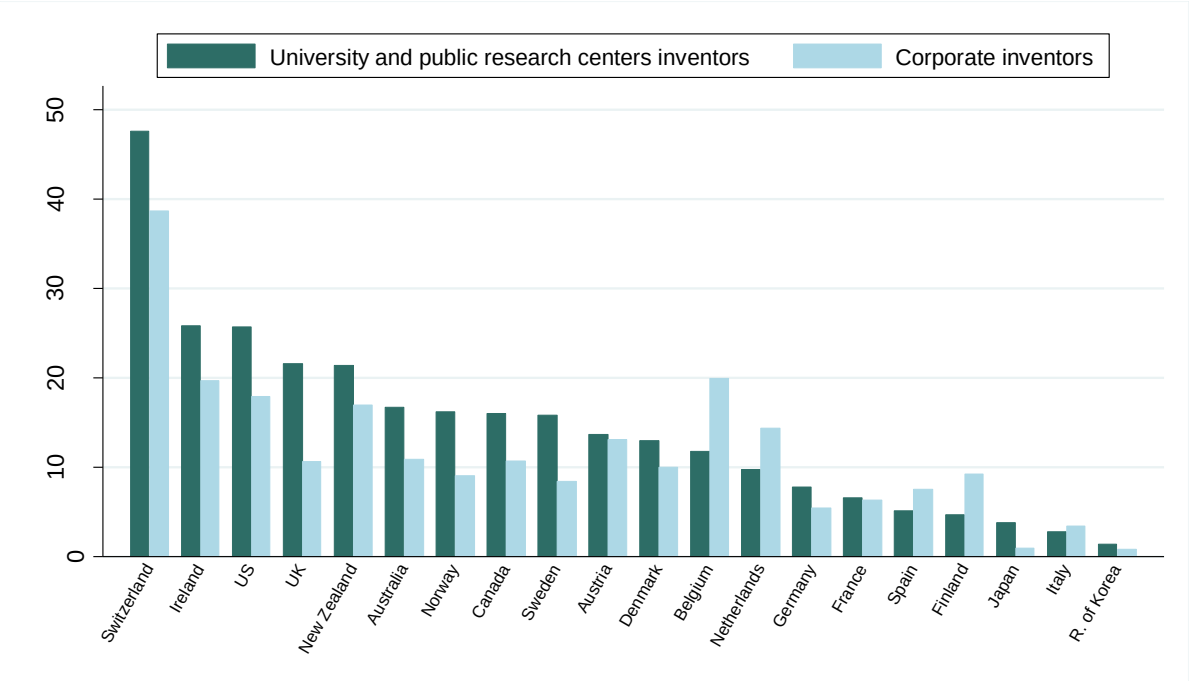
China and India stand out as the main origins of inventor immigrants in the US. Other coutries seem to have an idiosyncratic distribution of origins; at the most, distributions reflect geographical proximity and shared historical, cultural, and language roots.

Academic institutions show larger immigration rates

The top patenting universities and public research centers feature some of the largest immigration rates amongst the top PCT applicants for the most important receiving countries. It is due to universities and public research organizations acting as privileged “points of entry” for high-skilled workers from abroad. This is relevant for evaluating the welfare-impact of skilled migration: if the brain drain occurs at the education stage, particularly, at the post-graduate education stage – sending countries may have higher chances to turn the brain drain into a brain gain, as future returnees require valuable skills that they can take home.

As can be seen in Figure E.2, university immigration rates are higher – and often considerably so – than corporate immigration rates in 15 out of the 20 selected destinations, confirming the greater openness of universities and research organizations. Only Belgium, the Netherlands, Finland, Spain and Italy do not show higher immigration rates for academics than corporate inventors.

Figure E.2: Immigration rates. University vs. corporate inventors, 2001-2010



Immigrant inventors contribute significantly to technological progress in their host countries

In order to investigate the contribution of immigrants in their host country economy, it is insightful to explore how many citations PCT applications receive that list migrant inventors. The economic literature has used the number of citations as a measure of a patent's underlying quality. In particular, one can look at the share of all patents with at least one listed inventor with migratory background and compare it with the share of inventors with migratory background listed in breakthrough patents – defined as the top-5% of patents in terms of citations received in the following 5 years after application. The results indicate that the proportion of immigrants is systematically larger among breakthrough inventions than among the whole universe of PCT patents. While the difference in citation outcomes may have a variety of explanations, it generally shows that immigrants contribute significantly to technological progress in their host countries.

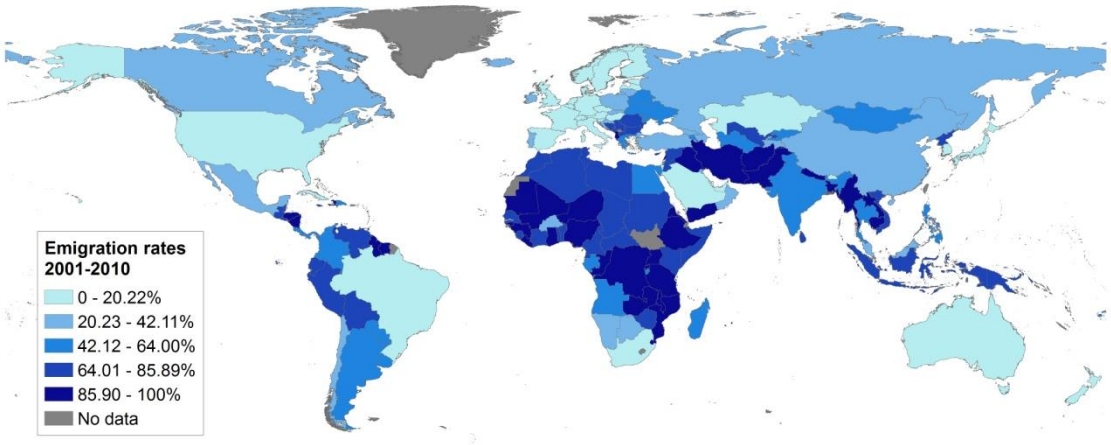
African and the Caribbean countries are the most affected by the brain drain of inventors

As mentioned above, the global share of inventors with migratory background stood at 7.46 percent from 1991 to 2000, and at 9.95 percent from 2001 to 2010. However, the inventor emigration rate of high income countries for these two time periods only stood at 4.99 percent and 5.92 percent, respectively. It was much higher for low, lower-middle and upper-middle income countries – standing, during 2001-2010, at 87.56 percent, 53.07 percent, and 30.30 percent, respectively.

Large differences emerge when computing emigration rates of inventors separately by continent. As expected – and as is the case for college educated individuals, the LAC region and, especially, the Africa region suffer the most severe brain drain of inventors, with ratios between 32 and 42 percent in both periods. Meanwhile, the other continents exhibit emigration rates in the range of 10-13 percent, with the exception of North America which only shows a 3 percent rate.

Figure E.3 depicts emigration rates – or "brain drain" rates – in a map for the 2001-2010 time window. The map confirms that low and middle income countries and especially African economies are the most severely affected by inventor "brain drain". However, some Latin American and Asian economies seem to suffer from the brain drain of inventors, too.

Figure E.3: Brain drain rates, 2001-2010



Inventor emigrants are more evenly distributed than immigrants

Contrary to relative inventor emigration rates, the largest absolute numbers of emigrant inventors come from high income countries, with the exception of China and India. In particular, the UK, China, Germany and India led the ranking in terms of total emigrants in 1991-2000. In 2001-2010 China and India took the lead and, jointly with some of the largest European countries, accounted for the large majority of emigrant inventors. Compared to immigration patterns, emigrant inventors are more evenly distributed across countries: the US alone received around 57 percent of all immigrant inventors during 2001-2010, whereas the six top emigration origins – namely, China, India, Germany, the UK, Canada and France – account for 57 percent of all emigrant inventors.

Table E.1: Share of emigrant inventors over total emigrants, by country

Total emigrants, 1991-2000			Total emigrants, 2001-2010		
Country	Emigrants	Share over total emigrants	Country	Emigrants	Share over total emigrants
UK	8,930	13.11	China	53,610	15.75
China	8,206	12.05	India	40,097	11.78
Germany	7,216	10.60	Germany	32,158	9.45
India	5,193	7.63	UK	27,746	8.15
France	3,350	4.92	Canada	21,315	6.26
Canada	3,286	4.83	France	19,123	5.62
US	3,205	4.71	US	11,131	3.27
Italy	2,068	3.04	Italy	9,820	2.88
Austria	1,993	2.93	Netherlands	9,132	2.68
Netherlands	1,986	2.92	Korea	9,127	2.68

Inventor data suggest that emigrants are more productive than their non-migrant co-nationals

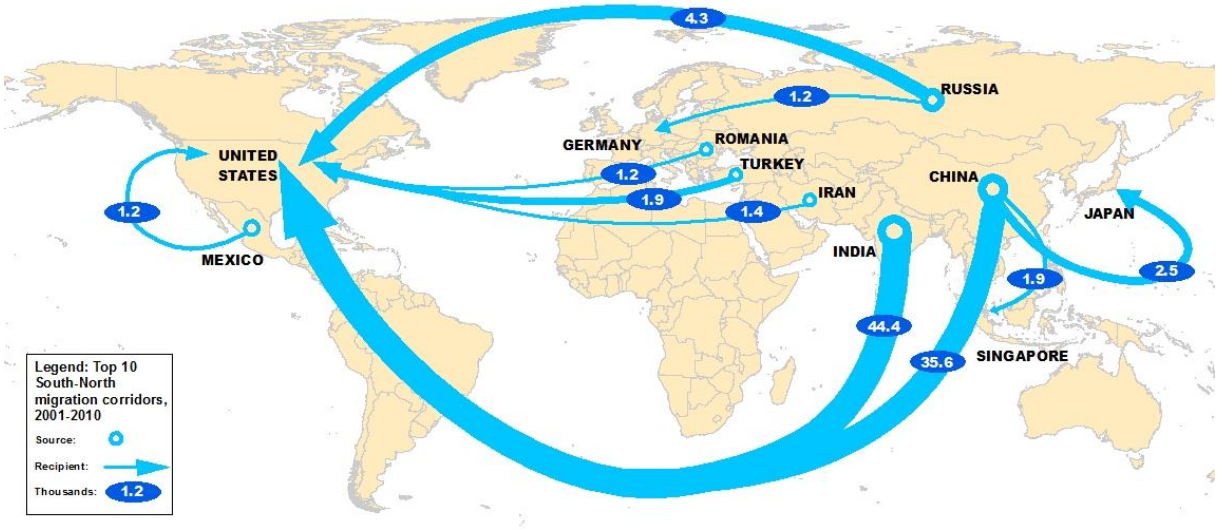
To better understand the economic implications of inventor brain drain, one can look at the performance characteristics of those who left their country as compared to those who stayed. In particular, one can explore the average citations received by patents listing "staying" inventors and the average citations received by patents listing emigrant inventors of the same countries. For most countries, the results indicate that emigrant inventors receive, on average, more citations than their non-migrating co-nationals.

The US appears in the majority of the most populated inventor migration corridors

When looking at the most populated bilateral corridors of inventors, the US appears most frequently in the rankings as a destination country, while other high income economies are usually the source country – with the exceptions of China and India. When removing the US from the analysis, intra-European flows of inventors dominate the top corridors, with interesting exceptions.

Figure E.4 looks at the top-10 migration corridors for which the sending country is not a high income economy for the 2001-2010 period. It graphically illustrates the importance of the US as a destination country. It also illustrates the importance of China and India as sending countries, with Russia, Turkey, Iran, Romania, and Mexico emerging as other top sending countries.

Figure E.4: Top-10 South-North migration corridors, 2001-2010



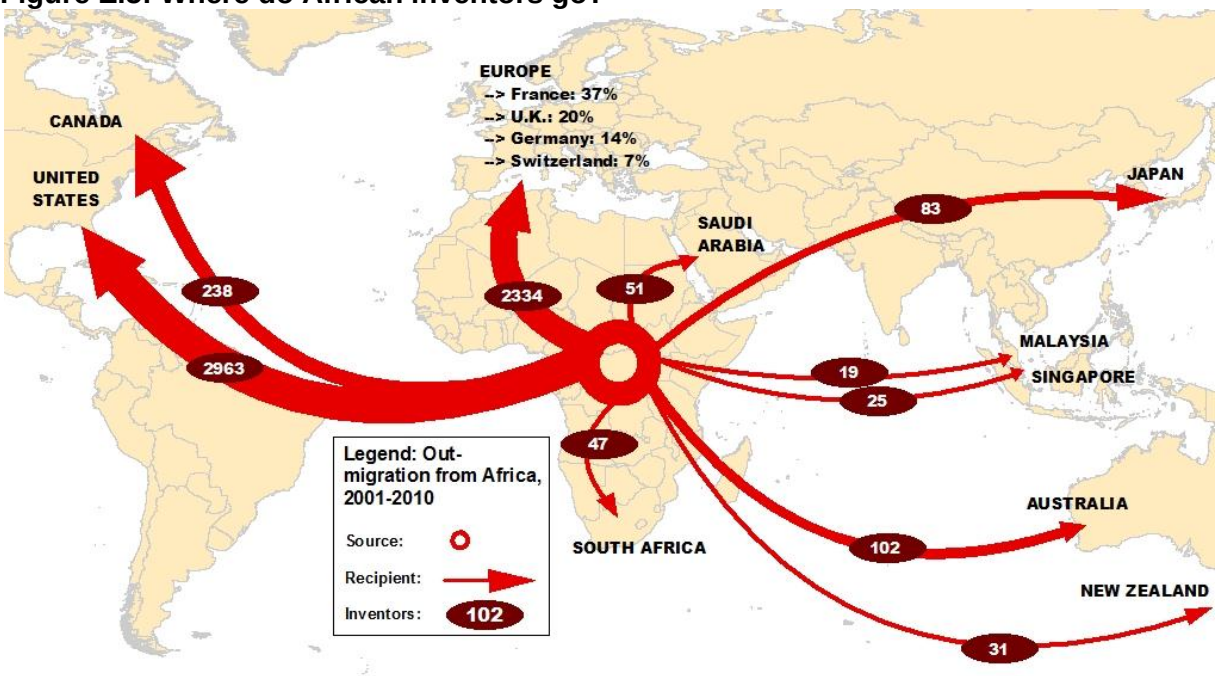
Where do African inventors go?

Inventors' brain drain appears to be disproportionally large in Africa and more pronounced than tertiary educated emigration rates. However, within the continent, countries such as South Africa, Botswana and Namibia seem to suffer less from the brain drain of inventors.

African inventor emigrants reside mainly in the US and in Europe (Figure E.5). During 2001-2010, they represented 1.53 percent of all US immigrants and 2.15 percent of all European immigrants. Within Europe, France hosted 37 percent of all African inventors residing in the continent, most likely reflecting a shared language and historical ties. After the US and Europe, other countries such as Canada, Australia, Japan and Saudi Arabia are

important destinations for African inventors. Interestingly, South Africa seems to be a regional hub in attracting talent from within the continent.

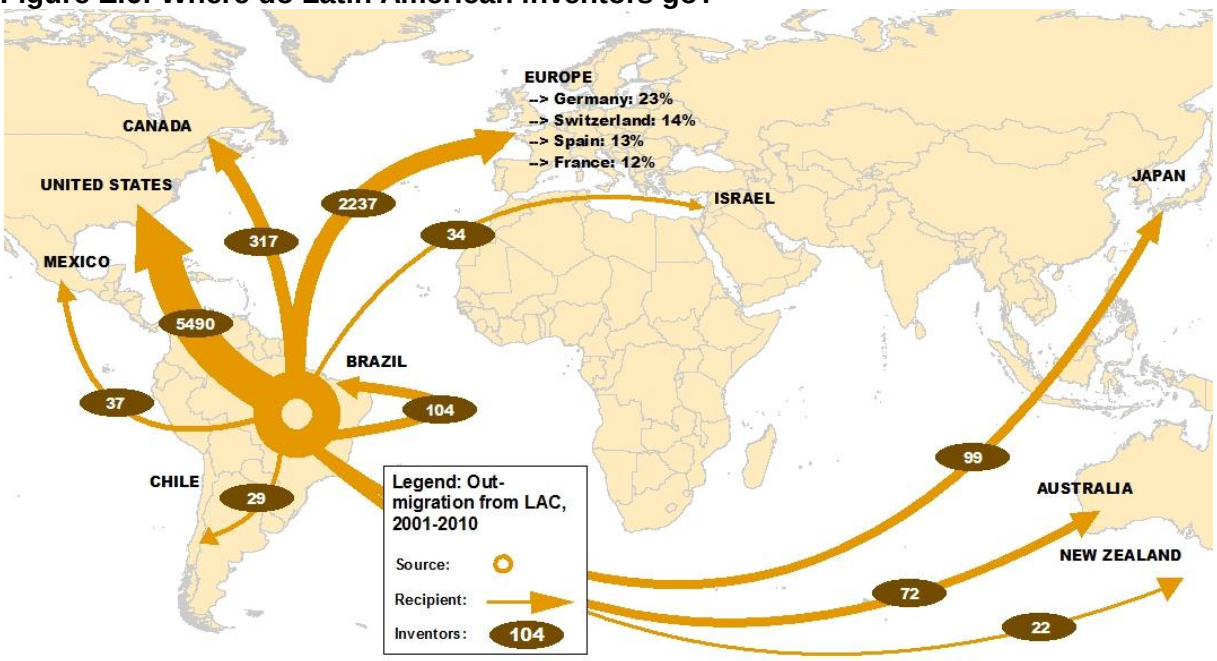
Figure E.5: Where do African inventors go?



Where do LAC inventors go?

For the LAC region, smaller states seem to suffer the most severe brain drain. Meanwhile, larger countries like Brazil, Colombia, Mexico, Chile and Argentina are less affected. Figure E.6 depicts the top-10 most popular destinations of LAC inventors. As for African inventor emigrants, the US and Europe lead the ranking. In relative terms, LAC inventors account for 3 percent of all immigrants in the US and for around 2 percent of all immigrants in Europe. However, the absolute number of LAC migrant inventors going to the US is more than double that of inventors going to Europe. Unlike for African inventors, France does not lead the ranking within Europe; Germany does so, followed by Switzerland, Spain and France. Historical ties and common language explain why Spanish attracts considerable talent from LAC. Interestingly, 3 out of 10 countries in this ranking are from the region itself – Brazil, Mexico, and Chile.

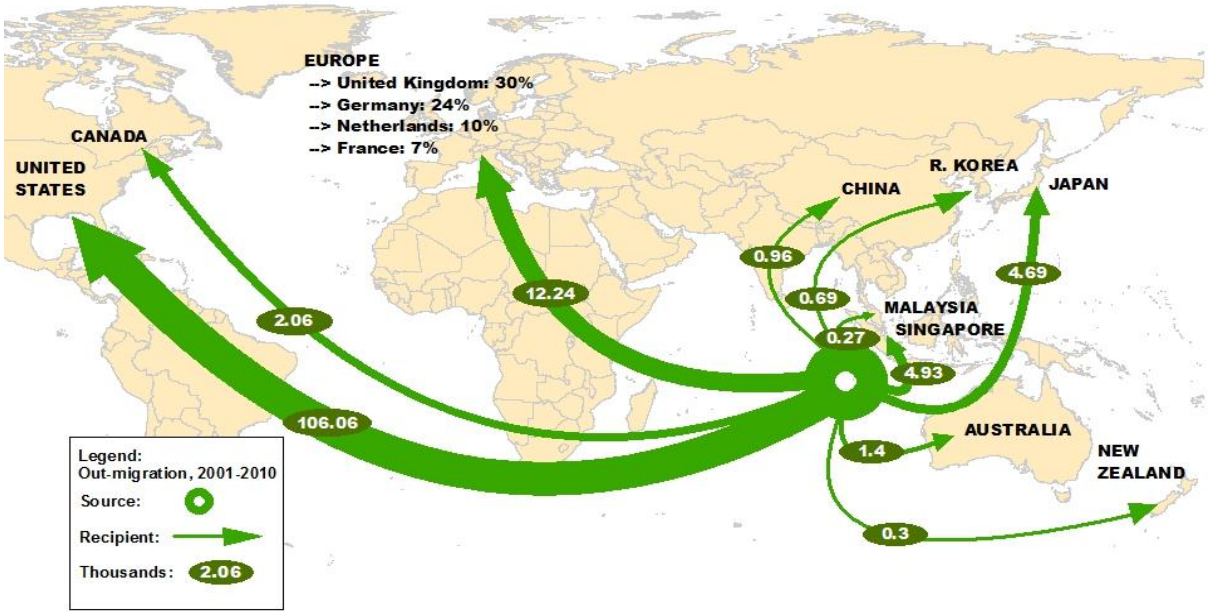
Figure E.6: Where do Latin American inventors go?



Where do inventors from the Middle East, South Asia, East Asia and Oceania and the Pacific go?

Figure E.7 depicts the top-10 most popular destinations of inventors from these regions. Compared to the LAC region and especially Africa, the absolute number of emigrant inventors from the Middle East, South and East Asia, Oceania and the Pacific is considerably larger. There are two main features that characterize emigration of inventors from these regions. First, the proportion of inventors going to the US as compared to other world regions is large. For example, there are nine times as many migrant inventors from this area emigrating to the US than to Europe. They represent 54.4 percent of all immigrant inventors in the US for the 2001-2010 period – substantially larger than the immigrant shares of African and LAC inventors in the US. China's and India's migration flows to the US largely explain this outcome, although other countries also play a role. Second, countries from the same region feature among the top-10 destinations. In particular, Japan, Australia, New Zealand, Singapore, the Republic of Korea, China and Malaysia attract large numbers of inventors from this part of the world.

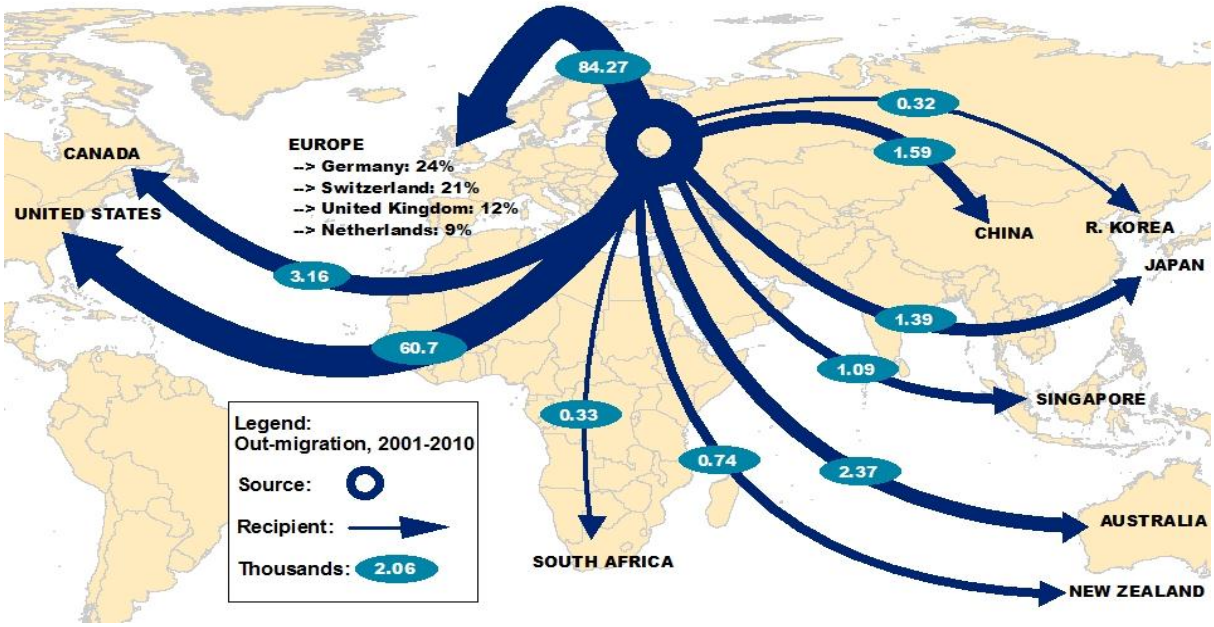
Figure E.7: Where do inventors from the Middle East, South Asia, East Asia and Oceania and the Pacific go?



Where do inventors from Europe and Central Asia go?

Different from the other regions analyzed, the majority of migrant inventors from this region do not move to the US, but stay in Europe and Central Asia – with most of them moving specifically within and to Western Europe. The US ranks second in attracting talent from this region, accounting for 31 percent of all immigrants in the US. The high income status of Western Europe, language ties, and the opening of Western European labor markets may explain the large intra-regional inventor flows. However, when exploring the most popular destination countries for European and Central Asian countries, the US remains the preferred destination for most individual origin countries.

Figure E.8: Where do inventors from Europe and Central Asia go?



Concluding remarks

This report describes a new global dataset on migrant inventors, using information on inventor nationality and residence available in PCT applications. By using patent data to map the migratory patterns of high-skilled workers, one can overcome some of the limitations faced by existing migration datasets.

Notwithstanding some caveats, this new database meaningfully captures a phenomenon of growing importance. Indeed, the descriptive overview presented in this report suggests that it is consistent with migratory patterns and trends as they emerge from census data. At the same time, the database opens new avenues for research, promising to generate fresh empirical insights that can inform both innovation policy and migration policy.

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BACKGROUND

In 2007, Member States of the World Intellectual Property Organization (WIPO) adopted the decision that formally established the "Development Agenda of WIPO". The decision consisted of the adoption of a set of 45 Development Agenda recommendations and the establishment of a Committee on Development and Intellectual Property (CDIP). The 45 recommendations are grouped into six clusters reflecting the main areas of focus of the Development Agenda. Cluster E, "Institutional Matters including Mandate and Governance", included recommendation 39, which reads as follows:

> "39. To request WIPO, within its core competence and mission, to assist developing countries, especially African countries, in cooperation with relevant international organizations, by conducting studies on brain drain and make recommendations accordingly."

The project entitled "Intellectual Property (IP) and Brain Drain" (CDIP/7/4 REV) implements this recommendation.

In line with the activities foreseen under this project, this report explores the potential of patent data to cast light on a specific category of high-skilled migrants, namely inventors who represent a key input into the innovation process. In particular, by exploiting information on inventor nationality and residence in patent applications, it maps the migration of scientists and engineers and establishes a partial geography of high-skilled migration flows.

1. INTRODUCTION

The mobility of people – and skilled workers in particular – has become an important pillar of the ongoing process of globalization. Many governments in high income countries have made efforts to attract skilled migrants from abroad – inciting what may be colloquially called a global competition for talent. Clear examples of this are the Indian and Chinese information technology (IT) workers, migrating to the United States (US) under the H-1B visa framework, or the blue card initiative launched by the European Union (EU).

In 2010, the estimated migrant population was around 213 million – a 58 percent increase compared to 1990 (United Nations, 2012). With population figures increasing at a similar pace, the world migration rate rose from 2.5 to 3.1 percent during this same period. These aggregate figures mask important variations across countries and types of migrants. Once one focuses on South-North migration, skilled migration or the intensity of migrants (emigrants and immigrants, of different skills, over the domestic population), important nuances emerge.

Thus, for instance, the proportion of migrants living in countries of the Organization for Economic Co-operation and Development (OECD) has tripled since the 1960s, and has doubled since the 1980s. Two-thirds of migrants live in high income countries, where around 9 percent of the population is foreign-born, compared to only 1.5 percent in non-high income economies (Freeman 2006). Besides, the number of highly educated immigrants – those with at least tertiary education – living in OECD countries increased by 64 percent during the 1990s, compared to the 23 percent increase of low-skilled migrants for the same period (Docquier and Rapoport 2009). Some low and middle income countries have seen their percentage of skilled population abroad fall, in large part due to growing domestic human capital endowments. However, this proportion is well above 50 percent for some small and least developed countries, especially in Africa and the Caribbean. The proportion of skilled individuals abroad is even larger when one focuses on the upper tail of the skills distribution. Indeed, recent studies (Barre et al. 2003; Meyer and Brown 1999) show that a large majority

of scientists and engineers trained in developing countries (around 30-50 percent) actually live in the developed world.

In order to better understand these phenomena, this report describes a new dataset on the international mobility of inventors listed in patent applications filed under the Patent Cooperation Treaty (PCT). Using this new dataset, the document describes in detail the mobility patterns of inventors over the 1991-2010 period. The underlying analysis is entirely descriptive and, by itself, will not offer insights into the causes and consequences of skilled migration – and its potential relationships with the IP. At the same time, this new dataset opens the door to answering a myriad of questions in the area of migration and innovation research.

The outline of this report is as follows: Section 2 reviews key contributions to the economic literature on the topic at hand and presents some important concepts used in the subsequent analysis. Section 3 summarizes the currently available databases to measure the brain drain phenomenon. Sections 4, 5 and 6 constitute the 'mapping exercise', consisting of a methodological note of the data sources (section 4) and a summary of the main cross-country patterns and trends emerging from the data (5 and 6). Section 7 offers concluding remarks.

2. MAIN CONCEPTS AND PREVIOUS CONTRIBUTIONS

2.1. Definitions and early studies on brain drain

International migration can be defined as "movements of persons who leave their country of origin, or the country of habitual residence, to establish themselves either permanently or temporarily in another country" (IOM, *2008*, pp. 495). A large body of literature on international migration focuses on *movements of skilled individuals* – the cross-border mobility of persons who earned, "either by tertiary level of education or occupational experience, the level of qualifications typically needed to practice a (highly-skilled) profession" (Op. Cit., pp. 494).

Although sizeable skilled migration flows occur between low income countries and between high income countries, it is migration from low and middle income to high income countries that has received the most attention from scholars and policymakers. This phenomenon has been often referred to as the *brain drain*, i.e., the "emigration of trained and talented persons from the country of origin to another country resulting in a depletion of skills resources in the former" (Op. Cit., pp. 492). Different from other international factor flows, the term 'brain drain' implies that net flows of talented people are heavily unbalanced in one direction (Salt 1997) and are greater than would be desired (Bushnell and Choy 2001).[3]

This phenomenon has the potential to seriously affect sending less developed economies, which already suffer from a severe scarcity of human capital endowments – Box 1 summarizes a list of the potential consequences of high-skilled migration.

Most pioneering studies from the 1970s emphasized the adverse consequences of the loss of nationally trained human capital who end up working and living abroad (Bhagwati and Hamada 1974; Bhagwati and Rodriguez 1975). These studies emphasized the depletion of human capital and human capital externalities, tax revenues, and innovative competences or absorptive capacity to predict negative effects of the brain drain for development. In the

[3] Note that the term 'brain drain' was allegedly coined for the first time by the British Royal Society to describe the outflow of scientists and technologists from the UK to the US and Canada in the 1950s and early 1960s.

meantime, sending countries' governments struggle to fill positions in key public sectors, such as health, education or research. Its absence may therefore have serious implications for growth and technological development.

Box 1: Possible effects of high-skilled international mobility

POSITIVE EFFECTS IN SENDING COUNTRIES
- Knowledge flows and collaboration, return of natives with foreign education and human capital, increased ties to foreign research institutions
- Export opportunities for technology
- Remittances and venture capital from diaspora networks
- Successful overseas entrepreneurs bring valuable management experience and access to global networks
- Increased incentive for natives to seek higher skills
- Possibility of exporting skills reduces risk/raises expected return from personal education investments
- May increase domestic economic return to skills

POSITIVE EFFECTS IN RECEIVING COUNTRIES
- Increased R&D and economic activity due to availability of additional high-skilled workers
- Entrepreneurship in high growth areas
- Knowledge flows and collaboration with sending countries
- Immigrants can foster diversity and creativity
- Export opportunities for technology
- Increased enrolment in graduate programs/keeping smaller programs alive
- Offset ageing of university professors and researchers
- Wage moderation in high growth sectors with labor shortages
- Immigrant entrepreneurs foster firm and job creation
- Immigrants can act as magnets for accessing other immigrant labor (network hiring effects)

NEGATIVE EFFECTS IN SENDING COUNTRIES
- "Brain drain" and lost productive capacity due to (at least temporary) absence of higher skilled workers and students
- Lower returns from public investment in tertiary education

NEGATIVE EFFECTS IN RECEIVING COUNTRIES
- Decreased incentive of natives to seek higher skills in certain fields, may crowd out native students from best schools

POSSIBLE GLOBAL EFFECTS
- Better international flows of knowledge, formation of international research/technology clusters (for example, Silicon Valley, CERN).
- Better job matches, including: greater employment options for workers, researcher's ability to seek the work most interesting to them and greater ability of employers to find rare/unique skill sets.
- International competition for scarce human capital may have net positive effect on incentives for individual human capital investments.

Source: Guellec and Cervantes (2002) and Regets (2001)**.**

2.2. A more nuanced view: remittances, brain gain and returnees

A more nuanced view of skilled migration, the so-called 'new brain drain literature' emerged in the 1990s and 2000s, placing greater emphasis on several feedback channels through which the brain drain can potentially be advantageous for origin countries.

For instance, the importance of the contribution made by emigrants' *remittances* to their origin country gross domestic product (GDP) is now a widespread idea both in the academic literature and in the media.[4] Data reveal that, broadly speaking, remittances greatly contribute to origin countries' gross national product (GNP) and are a valuable source of foreign currency.

Recorded remittance flows to low and middle income economies are estimated at around US dollar 406 billion in 2012, and are expected to reach US dollar 534 billion by 2015 (World Bank, 2012). Thus, remittances to these countries constitute nowadays three times the

[4] See *The Economist*, 'New rivers of gold', April 28th 2012

value of official development assistance (op. cit.). Remittances are highly uneven across recipient countries, both in absolute terms and as a percentage of GDP. In 2012, the top 5 recipient countries in absolute terms were India (70 US$ billion), China (66 US$ billion), the Philippines (24 US$ billion), Mexico (70 US$ billion), and Nigeria (21 US$ billion). In 2011, the top 5 recipients as a percentage of GDP were Tajikistan (47%), Liberia (31%), Kyrgyzstan (29%), Lesotho (27%) and Moldova (23%).

Another key concept in the literature is that of *brain gain*. Although the concept is currently used as a synonym of any gain the origin country of emigrants may experience from the emigration of their educated manpower, brain gain was initially used to describe the fact that the prospect of migration can induce individuals to invest in their education and form a socially desirable level of human capital at home (Mountford 1997; Stark et al. 1997).[5] However, not all educated workers with the prospect of emigrating can know for certain that they will be able to emigrate in the future. If a significant proportion of well-educated persons do not leave, the country's human capital lost when some of the educated workforce leave will be compensated by those who stay and who would not have invested in their education without the prospect of emigrating.

An additional 'compensation' effect of high-skilled emigration is the possible *return migration* of expatriates to their home countries. Return migration after a period of time working or studying abroad may benefit the origin country of the migrant in multiple ways. Returning skilled migrants are likely to acquire skills, expertise and knowledge during their migration spell, which increases the average level of human capital of their home countries once they are back, as well as the international diffusion of ideas. Returning migrants may also have accumulated financial capital while abroad, as well as managerial skills, global networks and business contacts. All these things put together may increase the rate of entrepreneurship in origin countries, with effects on employment creation, technology adoption and production, prospective international collaborations, and ultimately economic growth (Dustmann and Kirchkamp 2002; Saxenian and Sabel 2008; Saxenian 2002).

2.3. Skilled emigration and diaspora networks

The migration literature defines *diasporas* as "part of a people, dispersed in one or more countries other than its homeland, that maintains a feeling of transnational community among a people and its homeland" (Chander 2001, pp. 1020). The potential benefits of diasporas can be realized by harnessing this "feeling" for the advantage of the home country, through the knowledge embedded in individuals as well as through their resources – such as capital or networks of colleagues and acquaintances (Kapur and McHale 2005). Diasporas are critical to convey access to relevant information otherwise inaccessible because of cultural, language, administrative, or geographical barriers, and therefore lower transaction costs associated with economic exchanges across borders – both for home and host country agents.

However, only recently has econometric-based evidence started to show a strong influence of diasporas abroad on trade (Gould 1994; Head and Ries 1998; Rauch and Trindade 2002), FDI (Gao 2003; Kugler and Rapoport 2007; Javorcik et al. 2011; Tong 2005), and ideas' diffusion (Agrawal et al. 2011; Kerr 2008; Foley and Kerr 2013).

[5] The concept of brain gain (or net brain gain) is also used in some studies to describe the situation in which a country is net recipient of skilled talent – skilled immigrants minus skilled emigrants.

3. HOW EXTENSIVE IS THE BRAIN DRAIN? THE STATE OF THE ART

3.1. Available migration datasets

Advances in our understanding of the effects of skilled worker migration have to a significant extent been due to new data becoming available over the last 15 years. In particular, the pioneering study by Carrington and Detragiache (1998) represents the first systematic attempt to construct a comprehensive dataset on emigration rates by educational attainment. Their study provides 1990 emigration rates for 61 sending countries to OECD destinations. They estimate skill levels by extrapolating the schooling levels of US immigrants by origin country to other receiving countries.

Similarly, Docquier and Marfouk (2006) estimate immigrant stocks in 30 OECD countries for 174 origin countries, for 1990 and 2000. In addition, Docquier et al. (2009) provide a gender breakdown and Beine et al. (2007) provide data broken down by the entry age of immigrants.[6] The OECD's DIOC-E database – based on 2000-2001 census data – offers to date the largest coverage, including numerous sending (233) and receiving (100) countries and territories, by gender, age, and educational attainment.[7] A more up-to-date version of DIOC (DIOC2005/06) is presented in Widmaier and Dumont (2011), using data for the years 2005 and 2006. However, only data from a limited number of destination countries (OECD countries) are used – plus a full list of more than 200 sending countries and territories.

The following subsection provides a summary of current brain drain figures from existing datasets. In particular, it first relies on Dumont et al. (2010) and Özden and Parsons (2013) to provide an overview of the DIOC-E database (release 2.0).[8] This database accounts for 72 percent of the estimated number of migrants worldwide and for a large share of migrants with tertiary level of schooling. Second, it provides evidence on a particular case of high skilled migration, i.e., the international mobility of Nobel Laureates.

3.2. Measuring the brain drain: stylized facts

3.2.1. The DIOC-E database[9]

The DIOC-E database is a joint effort of the OECD and the World Bank, with support from the Agence Française de Développement (AFD). The database consists of information on migrants by destination country based on population censuses (mostly from OECD countries) or population registers (mostly from non-OECD countries) from around 2000. This means collecting immigration data in 89 destination countries (28 OECD countries and 61 non-OECD countries), of migrants from about 200 countries and areas of origin. These 89 receiving countries represent about 55 percent of the world population of 15 years old and over, that host about 72 percent of the world's migrants. All in all, the database includes 110 million migrants, with about 75 million of them living in OECD countries and 35 million in non-OECD countries.

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[6] Some of these datasets are available at: http://perso.uclouvain.be/frederic.docquier/oxlight.htm (accessed 9th May 2013).

[7] DIOC-E stands for "Database on Immigrants in OECD Countries – Extended". This dataset is available at: www.oecd.org/migration/dioc/extended (accessed 9th May 2013). For a description of release 2.0 of this database, see Dumont et al. (2010).

[8] Although release 3.0 exists, Dumont et al. (2010) and the figures presented there are based on release 2.0. No important differences between the two versions are worth reporting. Note also that the most up-to-date version, DIOC2005/06, is not used. Despite providing figures for the years 2005 and 2006, this version of the dataset is based on a relatively smaller number of receiving countries.

[9] This section summarizes Dumont et al. (2010), Docquier and Marfouk (2006) and Özden and Parsons (2013).

The share of the global population born in a foreign country stood at around 2.4 percent in 2000. Several OECD countries exhibit large shares of immigrants relative to their total population, notably Luxembourg (37%); Australia: (27%); Switzerland: (25%); New Zealand: (23%). Similarly, selected non-OECD countries also see a large immigration share, notably Singapore (23%), Estonia (22%), Belize (21%) and Latvia (21%). By contrast, Mexico (0.4%) and Japan (1.1%) account for the lowest shares of immigrants in OECD countries.

The following countries account for the largest emigration stocks in absolute terms: Mexico (8.4 million migrants abroad), Ukraine (4.7 million), Bangladesh (3.8 million), the United Kingdom (UK), (3.4 million), Germany (3.4 million) and the Russian Federation (3.1 million). However, some differences arise when looking at the educational attainment of the skilled emigrant population across countries. Thus, the countries with the largest stocks of skilled emigrants in absolute terms are Ukraine (1.2 million), the UK (1.2 million), India (1 million), Germany (1 million), China (0.9 million), and the Philippines (0.9 million) – see Table 1.

Table 1: Stock of emigrants. Census 2000

Countries	Skilled emigrants
Ukraine	1,239,470
UK	1,179,147
India	1,087,881
Germany	979,517
China	912,219
Philippines	909,922
Russian Federation	865,374
US	527,688
Kazakhstan	520,010
Poland	495,904
Mexico	485,367
Canada	436,930
Republic of Korea	431,780
France	414,417
Viet Nam	356,362
Italy	324,120
Japan	309,431
Iran	300,841
Belarus	288,190
Romania	275,728
Pakistan	272,986
Cuba	243,024
Morocco	238,489
Uzbekistan	220,813
Colombia	220,119
Algeria	219,483
Ireland	209,085
Netherlands	204,926
Jamaica	197,158
Puerto Rico	194,311

Source: Docquier and Marfouk (2006) and Dumont et al. (2010)

These figures only give an incomplete picture of the extent to which countries suffer from the emigration of their talented individuals. One also needs to look at emigration levels relative to an origin country's population. In particular, one can define the emigration rate of a given country *i* as the share of country *i*'s native population residing abroad relative to country *i*'s total native population. Similarly, the emigration rate of skilled people, or the 'brain drain' rate, is computed as the tertiary educated nationals living abroad over the tertiary educated national population. Since data on the native-born versus foreign-born by origin country are frequently unavailable, the denominator typically includes both the skilled nationals living

abroad plus the skilled residents living in country *i* – regardless of whether they are native- or foreign-born.

As mentioned above, the global emigration rate was estimated to be around 2.4 percent in 2000. However, this rate masks significant regional differences: Europe, Latin America and the Caribbean (LAC) and Oceania have the highest emigration rates, while Africa, Asia and North America have emigration rates which are less than half of those regions, as shown in Table 2. In all regions, the emigration rate for the tertiary educated is significantly higher than the total emigration rate. The global emigration rate of high-skilled persons from Africa, estimated at 10.6 percent, is notoriously high, especially when compared to other regions of origin and the world average of 5.4 percent. LAC also shows a relatively high emigration rate for high-skilled persons (8.8 percent).

Table 2: Emigration rates Census 2000, by country groups

	Global emigration rates	
	Emigration rate	Skilled emigration rate
World	2.38	5.44
High income	3.05	3.80
Upper-middle income	4.41	6.91
Lower-middle income	2.02	6.67
Low income	1.73	6.28
Africa	2.00	10.56
Asia	1.16	4.32
Europe	5.80	7.81
Latin America	5.70	8.79
North America	0.92	1.38
Oceania	4.52	7.21

Notes: Income groups according to the World Bank classification of 2000
Source: Dumont et al. (2010) and DIOC-E (release 2.0).

Emigration rates and skilled emigration rates vary markedly within world areas. Table 3 shows the top 15 and bottom 15 countries, respectively, most and least affected by the brain drain. The smallest and/or poorest countries show the highest rates of high-skilled migration. Some of these rates are even above 50 percent – for example, for Barbados, Guyana, Haiti, Trinidad and Tobago, Belize, Mauritius and Tonga – meaning that more tertiary educated people born in those countries live abroad than in the country itself. On the other side, populated and/or high income countries tend to show low high-skilled emigration rates ,notably, the US, Japan, Saudi Arabia and China.

Table 3: Emigration rates 15-top and 15-bottom countries

	Emigrants (thousands)	Skilled emigrants (thousands)	Emigration rate (percentage)	Skilled emigration rate (percentage)
Top 15 countries skilled emigration rate				
Barbados	90.10	24.33	28.45	90.42
Guyana	317.60	77.81	38.43	77.79
Haiti	523.00	94.14	9.27	70.41
Trinidad and Tobago	277.60	82.45	22.49	66.65
Belize	44.40	8.88	23.21	59.46
Mauritius	95.90	24.07	9.81	53.84
Tonga	41.30	4.42	40.54	51.88
Jamaica	791.80	197.16	31.34	46.06
Cambodia	239.80	37.17	3.13	43.70
Seychelles	9.10	1.73	13.01	40.64
Mozambique	379.60	24.29	3.57	40.57
Sierra Leone	122.30	16.14	4.50	39.14
Congo	79.60	26.98	4.11	38.25
Zimbabwe	206.60	45.66	2.73	37.37
Ghana	213.80	56.02	1.77	33.49
Bottom 15 countries skilled emigration rate				
Thailand	305.40	80.32	0.65	3.50
Burkina Faso	34.40	3.37	0.55	3.17
India	2,621.40	1,087.88	0.38	2.91
Spain	1,074.40	184.80	3.04	2.80
Nigeria	318.60	151.34	0.47	2.73
Nepal	647.90	9.72	4.30	2.71
Brazil	702.40	163.66	0.57	2.60
Indonesia	996.60	140.52	0.67	2.41
Qatar	3.40	1.52	0.73	2.04
China	2,513.00	912.22	0.26	1.96
Myanmar	219.80	33.41	0.68	1.88
United Arab Emirates	27.70	4.57	1.11	1.28
Japan	686.10	309.43	0.63	0.99
US	1,221.50	527.69	0.54	0.83
Saudi Arabia	42.30	13.37	0.33	0.81

Source: Dumont et al. (2010) and DIOC-E (release 2.0).

From the DIOC-E database it is also possible to look at high-skilled individuals in terms of the occupation they perform, regardless of their level of education – although many high-skilled occupations also require a tertiary education. In terms of occupation, the high-skilled can be defined as categories 1 or 2 of the International Standard Classification of Occupations (ISCO) classification, namely Legislators, Senior Officials and Managers and Professionals (ISCO 88). In the underlying dataset, 79 destination countries report data by occupation, of which 29 are OECD destinations.[10]

The first four columns in Table 4 show the top OECD and non-OECD destinations attracting the largest number of high-skilled migrants – as defined through their occupation. The US is by far the most attractive destination, hosting almost as many category 1 or 2 high-skilled migrants as do all remaining OECD countries put together. The next largest destinations include Canada, the UK and Australia, followed by the largest economies in Western Europe. Interestingly, the UK ranks higher than Australia in terms of attracting category 1 and 2 skilled migrants – despite Australia attracting many more migrants as defined by tertiary education level. The UK also attracts as many migrants as France and Italy combined.

[10] A notable exception is the Republic of Korea.

As for non-OECD countries, Russia is home to 1.8 million high-skilled immigrants according to the same definition. This figure is at least in part due to the definition of the foreign-born. In particular, many migrants born in the Soviet Union count as foreign born in Russia following the dissolution of the Soviet Union and the redrawing of international borders. Aside from countries of the Former Soviet Union, Israel, China Hong Kong SAR, Venezuela, South Africa and Brazil rank among the largest receivers of high-skilled migrants.

Table 4: Top-20 High-Skilled Occupation Immigrant and Emigrant Stocks, 2000

OECD Destination	2000 High-Skilled Immigrant Stock	%	Non-OECD destination	2000 High-Skilled Immigrant Stock	%	Origin Country	2000 High-Skilled Emigrant Stock to the OECD	%
US	4,005,449	49.0	Russia	1,837,180	22.5	UK	637,458	11.4
Canada	871,815	10.7	Ukraine	514,484	6.3	India	531,669	9.5
UK	785,314	9.6	Israel	176,958	2.2	Germany	447,747	8.0
Australia	599,510	7.3	China, Hong Kong SAR	162,578	2.0	China	385,101	6.9
France	451,720	5.5	Venezuela	146,030	1.8	Philippines	352,191	6.3
Italy	183,615	2.2	S. Africa	114,396	1.4	Mexico	265,662	4.7
Germany	170,190	2.1	Brazil	112,313	1.4	Canada	231,172	4.1
Spain	153,880	1.9	Serbia & Montenegro	42,740	0.5	US	192,834	3.4
Switzerland	133,477	1.6	Puerto Rico	36,834	0.5	Vietnam	182,824	3.3
N. Zealand	103,827	1.3	Malaysia	35,500	0.4	France	181,910	3.2
Portugal	83,842	1.0	Croatia	31,536	0.4	Italy	172,914	3.1
Sweden	75,435	0.9	Latvia	30,090	0.4	R. Korea	155,943	2.8
Ireland	69,972	0.9	Chile	26,851	0.3	Poland	144,650	2.6
Austria	67,452	0.8	Kyrgyzstan	24,680	0.3	Taiwan	124,042	2.2
Japan	63,298	0.8	Estonia	22,261	0.3	Iran	123,841	2.2
Greece	60,068	0.7	Armenia	21,313	0.3	Algeria	120,687	2.2
Belgium	54,330	0.7	Lithuania	19,127	0.2	Japan	116,206	2.1
Turkey	54,298	0.7	Thailand	17,974	0.2	Russia	115,879	2.1
Mexico	36,653	0.4	Paraguay	15,875	0.2	Ireland	112,705	2.0
Poland	35,610	0.4	Romania	13,800	0.2	Jamaica	105,180	1.9
Total	**8,177,434**	**100**	**Total**	**8,177,434**	**100**	**Total**	**5,603,895**	**100**

Source: Özden and Parsons (2013). Columns with '%' indicate, for each country, the share of immigrants, emigrants and emigrants to OECD countries over total immigrants, emigrants and emigrants to the OECD countries.

The final two columns of Table 4, list the top 20 emigrant stocks for those countries that send high-skilled migrants to the OECD, as defined by the occupational classification. The UK sends more occupational high-skilled migrants abroad to the OECD than any other country in the world, including India and China both of which have populations of over one billion and to differing extents encourage emigration. What is clear from Table 4 is that high-skilled immigrant stocks are extremely concentrated with the top few destinations accounting for a disproportionately large percentage of the total. Concurrently, the numbers of source countries participating in sending their natives abroad has increased significantly over the last few decades (Özden et al. 2011), such that the overall picture is one of diversification at the origin but concentration at the destination.

Bilateral figures enable us to identify the top migration corridors containing ISCO88 category 1 and 2 – Table 5. The first column shows the top 20 migration corridors, while the second shows the top 20 in the absence of the most significant receiver – namely the US which accounts for 16 of the top 20 corridors to the OECD. Aside from the US, many of the largest high-skilled migrant corridors to the OECD are from elsewhere in the OECD. Of the remaining, many represent movements from former colonies: for example, from North Africa to France and from India and Africa to the UK. Six of the top twenty high-skilled corridors, once the US has been excluded, are to Canada, which draws upon both OECD (e.g. UK,

Italy, US) and non-OECD (e.g. China and India) origins. The UK features in nine of the largest high-skilled bilateral migration corridors, as both a receiving and a sending country.

Table 5: Top-20 High-Skilled Occupation Immigrant Corridors, 2000

Corridor (incl. US)	2000 High Skilled Immigrant Stock	Corridor (excl. US)	2000 High Skilled Immigrant Stock
India-US	368,154	UK-Australia	184,227
Philippines-US	300,159	UK-Canada	121,290
China-US	270,905	Algeria-France	109,072
Mexico-US	255,705	India-UK	82,448
Germany-US	186,720	Ireland-UK	64,687
Canada-US	184,659	Morocco-France	63,787
UK-Australia	184,227	USA-Canada	63,765
UK-US	176,419	N. Zealand-Australia	57,576
Vietnam-US	133,465	China-Canada	50,300
R. of Korea-US	132,024	China, Hong Kong SAR-Canada	48,350
UK-Canada	121,290	India-Canada	44,965
Algeria-France	109,072	UK-Ireland	43,902
Taiwan-US	108,664	Germany-UK	43,380
Puerto-Rico-US	91,435	UK-New Zealand	42,951
Japan-US	91,149	Poland-Germany	39,938
Cuba-US	90,919	USA-UK	37,595
India-UK	82,448	South Africa-UK	35,095
Jamaica-US	78,077	Germany-Switzerland	33,292
Iran-US	73,328	Italy-Canada	31,830
Ireland-US	64,687	Kenya-UK	31,590
Total	**8,177,434**	**Total**	**4,162,633**

Source: Özden and Parsons (2013).

3.2.2. The Nobel Laureates' brain drain

As a more anecdotal exercise, this subsection looks at the migratory background of 629 Nobel Laureates in Physics, Chemistry, Medicine and Physiology, and Economic Sciences, from 1901 onwards – except Economic Sciences, for which the first Nobel Prizes was only awarded in 1969. More specifically, data on the place of birth and the country affiliation at the time of award are collected from the Nobel Foundation official site (www.nobelprize.org), and several migration-related metrics are presented.

Our sample is composed of 194 Laureates in physics, 163 Laureates in chemistry, 201 Laureates in medicine or physiology, and 71 Laureates in economic sciences, coming from a large number of origin countries. One can define an internationally mobile Laureate as one whose country of birth differs from the country of residence at the time of the award. All in all, 187 out of 629 Nobel laureates are mobile, according to this definition, which translates into a relatively high migration rate of about 30 percent. Strikingly, the vast majority of these 187 mobile laureates moved to the US (100 cases – see last columns of Table 6), where they received their award. Other large receiving countries are the UK, Germany and Switzerland.

Table 6: The Nobel Laureates' Brain Drain. Top-15 countries

No. of Nobel Laureates, by country of birth		No. of Laureates residing abroad at the time of award, by country of birth		No. of Laureates residing abroad at the time of award, by country of residence	
US	221	Germany	21	US	100
UK	74	Poland	18	UK	24
Germany	67	UK	13	Germany	20
France	33	Canada	11	Switzerland	13
Russia	18	Russia	10	France	7
Poland	18	Austria	10	Canada	4
Sweden	16	Italy	8	Sweden	3
Netherlands	16	France	8	Russia	3
Japan	15	Netherlands	8	Denmark	2
Austria	14	Australia	7	Israel	2
Canada	13	Hungary	7	Belgium	2
Switzerland	12	China	6	Austria	2
Italy	12	Japan	6	Argentina	1
Australia	10	India	4	Netherlands	1
Hungary	8	US	4	Australia	1

Source: www.nobelprize.org (accessed, 31st July 2013)

In addition, a large part of the mobile Laureates originate from Western and Eastern European countries – see the central columns of Table 6. High income countries such as Germany, the UK, and Canada are both receivers and providers of large numbers of Nobel Laureates. However, a small proportion of them also moved from middle income economies. Similar to high-skilled migrants by education or occupation, immigrant stocks of Nobel Laureates are highly concentrated (mainly in the US), although there seems to be a greater diversity of origins.

3.3. Limitations of existing data sources

Notwithstanding their value for economic research, census-based datasets have certain limitations. First, migrant stock datasets typically cover only a single year, or two at the most. This is a drawback, as researchers cannot exploit time-series variation in the data to study the causes and consequences of migration.

Second, OECD countries differ in how they define educational attainment. In particular, some countries record educational certification instead of the highest grade of schooling completed, complicating comparability across countries. Moreover, the skills' portfolio acquired through formal education may differ substantially across countries, which is exacerbated when the sample includes non-OECD countries.

Finally, skill levels still differ markedly among skilled workers. The majority of the existing datasets provides a skills breakdown according to three schooling levels, which only offers a rough differentiation of skills. In particular, tertiary education may include non-university tertiary degrees, undergraduate university degrees, postgraduate degrees and doctoral degrees. The economic effects of migration in the sending and host countries will likely vary across different types of tertiary educated individuals.

Focusing on inventor migration as captured in patent applications, as this report does, can overcome many of the limitations associated with migrant stock data. It captures one specific class of high-skilled workers that is bound to be more homogenous than the group of tertiary educated workers as a whole. In addition, inventors arguably have special economic importance, as they create knowledge that is at the genesis of technological and industrial transformation. Thus, the use of patent-inventor data for migration analysis implies the direct

measurement of migrants' contribution to innovation in their destination countries, in particular in relation to science-based and advanced technologies. Moreover, when exploited together with patent citations and joint patenting between inventors, it is possible to track, respectively, knowledge flows and social networks among inventors from the same origin country, either within the same destination country or back towards the country of origin. Further, it is also possible to track returnee inventors, and the implications of this phenomenon for sending countries' development (Breschi et al. 2013).

Some studies have looked at migrant inventors using information from patent applications (Agrawal et al. 2011; Breschi et al. 2013; Kerr 2008). In particular, they have sought to identify the likely cultural origin of inventor names disclosed in patent data. This approach has produced important insights. However, the cultural origin of inventor names may not always indicate recent migratory background. The migration history of certain ethnicities spans more than one generation – for example, Indian and Chinese immigrants in the US or Turkish immigrants in Germany. Conversely, one may overlook immigrant inventors with names sharing the same cultural origins as the host country – for example, Australian or British immigrants in the US.

As the following section will show in detail, PCT patent applications contain direct information on the nationality of inventors as well as their country of residence at the time of application. As a result, these data offer a valuable resource for better understanding high-skilled migration flows and their implications for innovation.

4. A NEW DATABASE ON THE INTERNATIONAL MOBILITY OF INVENTORS

4.1. Patents and the PCT system

One can build a database on the international mobility of inventors by deriving information on the migratory background of inventors from patent applications filed under the PCT.[11] Accordingly, it is useful to first provide some background on the patent system and especially on the PCT system, which facilitates the process of seeking patent protection in multiple jurisdictions.

To obtain a patent right, individuals, firms, or other entities must file an application that discloses the invention to the patent office and eventually to the public. In most cases, a patent office then examines the application, evaluating whether the underlying invention is novel, involves an inventive step, and is capable of industrial application. Economic researchers have long used patent applications as a measure of inventive activity. The attraction of patent data relies on such data being available for a wide range of countries and years, and for detailed technology classes (Hall 2007). In addition, patent documents contain information on the application's first filing date and on the applicants and inventors, including their geographical origin – down to the level of street addresses. Studies have made use of patent data to investigate the innovative behavior of firms, localized knowledge spillovers, international knowledge flows, networks of co-inventors and inventor mobility.

The PCT is an international treaty administered by WIPO offering patent applicants an advantageous route for seeking patent protection internationally. The treaty came into force in 1978; starting with only 18 members back then, there were 148 PCT contracting states in 2013.[12]

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[11] For a more detailed description of the data sources and the database, see Miguelez and Fink (2013).
[12] For a list of member states, and the date at which states became bound by the PCT see: http://www.wipo.int/pct/en/pct_contracting_states.html.

The key to understanding the PCT system's rationale is to realize that patent rights are territorial in nature, meaning that they only apply in the jurisdiction of the patent office that grants the right. A patent applicant seeking to protect an invention in more than one country has two options. The applicant can file applications directly at the patent offices in the jurisdictions in which the applicant wishes to pursue a patent – this approach is referred to as the "Paris route" towards international protection.[13] Alternatively, the applicant can file an application under the PCT. Choosing the "PCT route" benefits the applicant in two main ways. First, the applicant gains additional time – typically 18 months – to decide whether to continue to seek patent protection for the invention in question and, if so, in which jurisdictions. Second, an International Searching Authority issues a report on the patent application that offers information on the potential patentability of the invention; this information can assist the applicant in deciding on whether and where to pursue the patent.[14]

Note that under the PCT system, the applicant still has to file applications in all jurisdictions in which the applicant eventually seeks protection. An international patent right, as such, does not exist; the ultimate granting decision remains the prerogative of national and regional patent offices. However, the additional time gained and the first opinion on the invention's patentability can be valuable for applicants at a relatively early stage of the patenting process, at which the commercial significance of an invention is still uncertain.[15] Accordingly, applicants have opted for the PCT route for somewhat more than 50 percent of international patent applications.

For the purpose of economic analysis – including migration analysis – the PCT system has two key attractions. First, the system applies one set of procedural rules to applicants from around the world and collects information based on uniform filing standards. This reduces potential biases that would arise if one were to collect similar information from different national sources applying different procedural rules and filing standards. Working with only a single national source may be a viable alternative for studying inventor immigration behavior for a particular country, but this approach could not reliably track migrating inventors on a global basis. In any case, as will be further explained below, national patent data records generally do not offer information on both the residence and nationality of inventors.

Second, PCT patent applications are likely to capture the commercially most valuable inventions. Patenting is a costly process and the larger the number of jurisdictions in which a patent is sought, the greater the patenting cost. An applicant will therefore only seek for a patent internationally if the underlying invention generates a sufficiently high return – higher than for patents that are only filed domestically.[16] Turning to the migration angle, one may hypothesize that the most valuable patent applications emanate from the most skilled inventors; so, while the focus on PCT patent applications clearly does not capture all patenting inventors, it is likely to capture the more important ones.

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[13] The Paris Convention for the Protection of Industrial Property affords applicants with a priority international filing privilege of 12 months, in order to file subsequent patent applications and benefit from the date of the first filing.

[14] In addition, applicants can request a preliminary examination of the patent application by an International Preliminary Examining Authority, which further assists them in their international filing decisions.

[15] See van Zeebroeck et al. (2009) and van Zeebroeck and van Pottelsberghe de la Potterie (2011).

[16] Several empirical studies have shown that PCT patent applications are more valuable as captured by different value proxies (Guellec and Van Pottelsberghe de la Potterie 2002; van Zeebroeck and van Pottelsberghe de la Potterie 2011).

4.2. Information on inventor nationality and residence in PCT applications

Similar to other patent documents, PCT patent applications contain information on the names and addresses of the patent applicant(s) (the owner), but also the names and addresses of the inventor(s) listed in the patent application. What is unique about PCT applications is that in the majority of cases they record both the residence and the nationality of the applicants. This has to do with the requirement under the PCT that only nationals or residents of a PCT contracting state can file PCT applications. To verify that applicants meet at least one of the two eligibility criteria, the PCT application form asks for both nationality and residence.[17]

In principle, the PCT system only records residence and nationality information for applicants and not inventors. However, it turns out that, until 2012, US patent application procedures required all inventors in PCT applications to be also listed as applicants. Thus, if a given PCT application included the US as a country in which the applicant considered pursuing a patent – a so-called designated state in the application – all inventors were listed as applicants and ensured that their residence and nationality information were available. Indeed, this is the case for the majority of PCT applications, reflecting the popularity of the US as the world's largest market.

Fortunately, a change to PCT rules in 2004 provided that all PCT applications automatically include all PCT member states as designated states, including the US. As a result of that, nationality of inventors became almost complete after that date.

However, the US enacted changes to its patent laws under the Leahy-Smith America Invents Act (AIA) that effectively removed the requirement that inventors be also named as applicants. Starting on September 16, 2012, PCT applicants (automatically) designating the US became free to list inventors without facing the requirement of indicating their nationality and residence – and, indeed, many applications quickly made use of this freedom.[18]

In a nutshell, this means that there is good coverage of inventors' residence and nationality information before 2004, excellent coverage from 2004 to 2011, and deteriorating coverage starting in 2012. The next section explains this in greater detail.

4.3. Data coverage

By December 31, 2012, the total number of PCT applications stood at 2,361,455. Incorporating all the entities taking part in a PCT patent application, this figure translates into 10,725,384 records – unique combinations of patent numbers and names. This includes, for each patent application, the names of the applicants, agents, the inventors, common representatives, special addresses for correspondence, and so-called applicant-inventors. Given the present interest in studying the migratory background of inventors, one can focus only on inventor and applicant-inventor records. This subgroup accounts for exactly 6,112,608 records.

Ideally, one would like to group these 6,112,608 records along uniquely identified inventors and applicant-inventors, in order to describe their migration patterns. However, the database does not provide for a single identifier for each inventor or applicant-inventor. The prior

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[17] See point 5.031 of the PCT Applicant's Guide: http://www.wipo.int/pct/guide/en/gdvol1/pdf/gdvol1.pdf (accessed 4th September 2013)

[18] Even though the PCT rule change giving effect to the flexibility provided by the AIA only entered into force on January 1, 2013, a transitional arrangement allowed PCT applicants to not list inventors as applicants any more as of September 16, 2013 – the date at which the relevant provision in the AIA took effect.

economic literature has disambiguated individual inventors through their names and surnames, as well as other information contained in patent documents.[19] Disambiguation refers to the identification of two or more inventors listed on several patents as the same person, based on the identity or similarity of their names and surnames. However, these approaches are far from perfect (Raffo and Lhuillery 2009). The present study did therefore not attempt to disambiguate inventor names. The raw records on inventors and applicant-inventors already enable meaningful analysis at the aggregate level. In particular, one can calculate immigration and emigration rates across countries and map bilateral inventor flows, whereby aggregate indicators are weighted by the productivity of inventors in terms of their number of patents. Clearly, name disambiguation would add important value, though the best disambiguation approach may partly depend on the research question at hand.

Box 2: Inventor-patent pairs

Given that patent databases do not usually provide for a single identifier for each inventor or applicant-inventor, one can treat each record in the PCT database as if it were a different individual. In particular, the unit of analysis will be the "inventor/applicant-inventor name – patent number" pair which, for the sake of simplicity, will be referred as "inventor-patent pair" – or IPP – throughout the document. A graphical representation of the primary unit of analysis is shown in Table 7. In there, each line is a record, or a so-called "inventor-patent pair" (IPP). Without loss of generality, one may refer to counts of IPPs also as inventors throughout the text – or migrant inventors, immigrant inventors, or emigrant inventors. However, since a disambiguation process of inventors' names is still lacking, one needs to have in mind that inventors and IPPs are not the same.

Table 7: IPPs plus nationality and residence

Patent number	Inventor name	Nationality	Residence
US2009048209	ANDERSON, Mark, E.	US	US
US2009048208	BADER, Aleksey, A.	RU	RU
NZ2000000102	BUCHANAN, Christina, Maree	NZ	NZ
US2009048222	CVETKOVIC, Slobodan	RS	US
US2009048210	HORODEZKY, Samuel, Jacob	CA	US
US2009048222	ILIC, Igor	RS	US
US2009048208	LYALIN, Sergey	RU	RU
US2009048209	MUNOZ, Paul, A.	US	US
EP2012001845	SAUNDERS, Brian	AU	GB
NZ2000000101	STEWART, Andrew	GB	NZ

Nationality and residence information are available for 4,928,076 of the 6,112,608 records, a coverage rate of 80.6 percent. The main reason for the less than complete coverage was already pointed out in the previous section: even though nationality and residence information is a compulsory field for applicants and applicant-inventors, it is not required for inventors that are not at the same time applicants. However, there are other reasons for incomplete coverage. For some records, either the nationality field or the residence field is missing; in selected cases both are missing. This could be due to the applicant omitting these fields in the original application or to errors in transferring information from the original patent application to the electronic filing system.[20]

[19] Lissoni et al. (2006) and Trajtenberg et al. (2006) have pioneered these disambiguation techniques.

[20] In a number of cases, the nationality and/or the residence field include the characters '**', '--', or 'ZZ'. These cases include records for which the country code specified in the address field does not coincide with the country code specified in the residence field; there are 28,600 such records. In addition, we find other causes for these characters: (1) geo-coding mistakes (for example, Israeli cities geo-coded in Iceland or Chinese cities geo-coded in Switzerland), (2) commuting (for example, workplace in Denmark, close to the German border, and residence in Germany), (3) colonial ties: addresses in the French Antilles, China Hong Kong SAR, and Faroe Islands are

Of the 1,184,532 records that do not offer complete nationality and residence information, 970,336 records – or 81.9 percent – relate to inventors that are not applicants; the remaining 214,196 records – or 18.1 percent – show missing or misrecorded information.

Figure 1 depicts the availability of nationality and residence information for all inventor and applicant-inventor records, from 1978 to 2012. It shows that this information is available for the majority of records throughout the PCT system's history. However, the coverage varies over time, standing between 60 and 67 percent during the 1990s, and between 70 and 92 percent during the 2000s. It increases markedly after 2004, reflecting the PCT rule change described above. Unfortunately, one can already observe a marked decline in the availability of nationality and residence information in 2012. As described above, following the implementation of the AIA, PCT applications did not have to list all inventors as applicants any more as of September 16, 2012.[21] Indeed, the incentive to not list inventors as applicants is strong, as it facilitates the subsequent management of the patent; in particular, decisions such as withdrawal or re-assignment of the patent only require the consent of a smaller number of parties – indeed, in most cases, there will only be a single applicant. As a consequence, the coverage of inventor nationality and residence information is bound to decline dramatically in 2013.

Figure 1: Coverage of nationality and residence information in PCT patents

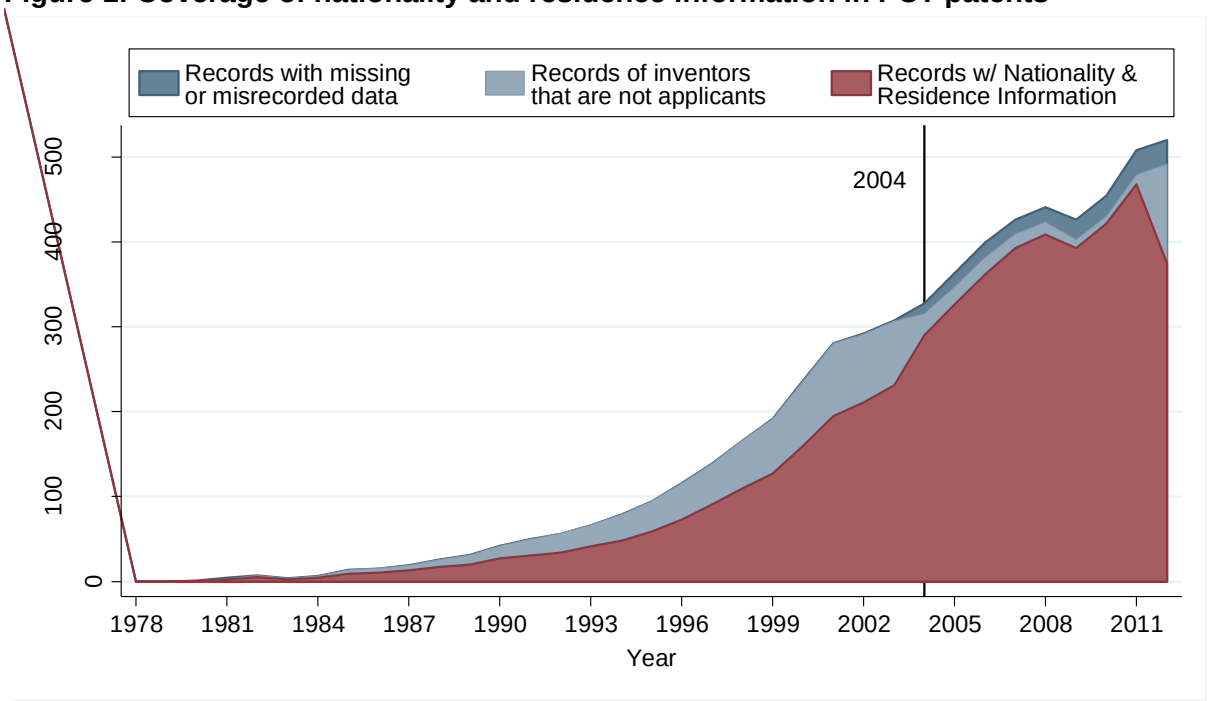

Table 8 shows how the coverage of nationality and residence information differs across countries. It includes those origins that account for most filings under the PCT. For the majority of countries shown, coverage lies above 90 percent and for most others, it is above 80 percent. US applications stand out as showing the lowest coverage, of around 66 percent. This has to do with the special US filing rule discussed above. Before 2012, non-US PCT applications needed to list inventors as applicant-inventors if they indicated the US as a designated state. However, US applicants generally file their applications at the US

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linked to individuals residing in, respectively, France, the UK and Denmark, and (4) temporary mobility (for example, an inventor has Israeli residence and nationality, but a US address country code).

[21] The PCT rule changes that.

patent office before submitting a PCT filing; thus, before 2004, they did not need to list the US as a designated state. The same reason likely explains the low coverage of nationality and residence information for Canada and the Netherlands. Due to their geographical proximity, many Canadian applicants first file an application at the US patent office before filing under the PCT. In the case of the Netherlands, a relatively small number of applicants account for a large share of PCT filings and those applicants appear to have a longstanding tradition to first apply directly at the US patent office.

Table 8: Total records and coverage of nationality and residence information

Country/territory name	Total records	Records with information	Records of inventors only	Coverage (percent)
Austria	40,411	37,755	1,773	93.43
Australia	70,720	67,621	2,491	95.62
Belgium	46,488	41,743	4,200	89.79
Brazil	14,116	12,983	947	91.97
Canada	112,627	91,166	20,399	80.95
Switzerland	84,521	78,600	4,847	92.99
China	233,506	213,837	18,684	91.58
Germany	751,509	712,426	35,547	94.80
Denmark	46,493	42,097	4,115	90.54
Spain	51,020	48,440	2,085	94.94
Finland	64,450	59,677	4,464	92.59
France	248,541	233,372	13,030	93.90
UK	257,266	236,760	15,807	92.03
Israel	63,644	58,599	4,682	92.07
India	50,777	45,552	4,656	89.71
Italy	95,691	90,309	4,726	94.38
Japan	909,360	854,176	42,204	93.93
Republic of Korea	234,775	204,994	29,348	87.32
Netherlands	128,236	94,616	22,773	73.78
Norway	24,294	23,139	978	95.25
New Zealand	11,806	11,258	433	95.36
Russian Federation	39,865	35,590	3,869	89.28
Sweden	114,614	101,894	12,134	88.90
Singapore	18,053	16,270	1,469	90.12
US	2,130,268	1,402,203	703,389	65.82
South Africa	10,594	10,015	502	94.53

Similar to Figure 1, Appendix 1 depicts the evolution of inventor nationality and residence information for a selection of countries accounting for substantial filing shares under the PCT. Importantly, it shows that the relatively low coverage for Canada, the Netherlands and the US is due to pre-2004 records. From 2004 to 2011, these three countries equally show high coverage shares. In addition, all countries show a marked decline in coverage in 2012, reflecting the procedural change introduced by the AIA.

In sum, PCT records generally offer good coverage of inventor nationality and residence information and, as such, represent a promising data source for migration research. Coverage is high for all countries between 2004 and 2011. Before 2004 it is high for most countries except Canada, the Netherlands, and the US. Unfortunately, as already pointed out, as of September 16, 2012, the ability of PCT records to provide information on inventors' migratory background appeared to be seriously undermined.

5. THE INTERNATIONAL MOBILITY OF INVENTORS – DESCRIPTIVE EVIDENCE

This section presents a descriptive overview of the database introduced in the section above. It focuses on inventor immigration and emigration stocks – see Box 3, and rates in different

parts of the world, and for a selection of countries. It also identifies the most important bilateral migration corridors. The analysis looks at differences across technologies as well. Section 6 then takes a closer look at African economies, countries from the LAC region, countries from Europe and Central Asia, and finally, countries belonging to South and East Asia, the Middle East, as well as Oceania and the Pacific regions. One reason for doing so lies on the fact that many countries account for only small numbers of patents – and consequently inventors – and they therefore do not appear in this section's aggregate overview.

Box 3: Metrics used in this study

In the migration literature, and in the present study, the *stock of immigrants* is defined as the number individuals with foreign nationality residing in a given country *i* in a given year or period of time. For the case of the present report, this will be the stock of immigrant inventors, or the stock of immigrant IPPs.

The *stock of emigrants* is defined as the number of people of a given nationality *i* residing abroad in a given year or period of time. Again, this report refers to the stock of emigrant inventors, or the stock of emigrant IPPs.

The *immigration rate* of a given country *i* in a given year is defined as the share of the foreign population over all residents of that country:

$$IM_i = \frac{immigrants_i}{residents_i}$$

The *emigration rate* of a given country *i* in a given year is defined as the share of the native population residing abroad, over all nationals of that country *i*. To make the figures comparable to tertiary educated emigration rates, the denominator includes also immigrant inventors residing in country *i*:

$$EM_i = \frac{emigrants_i}{(emigrants_i + residents_i)}$$

In the migration literature, when the emigration rate is computed for the tertiary educated individuals, the resulting ratio is often termed as the *brain drain* rate.

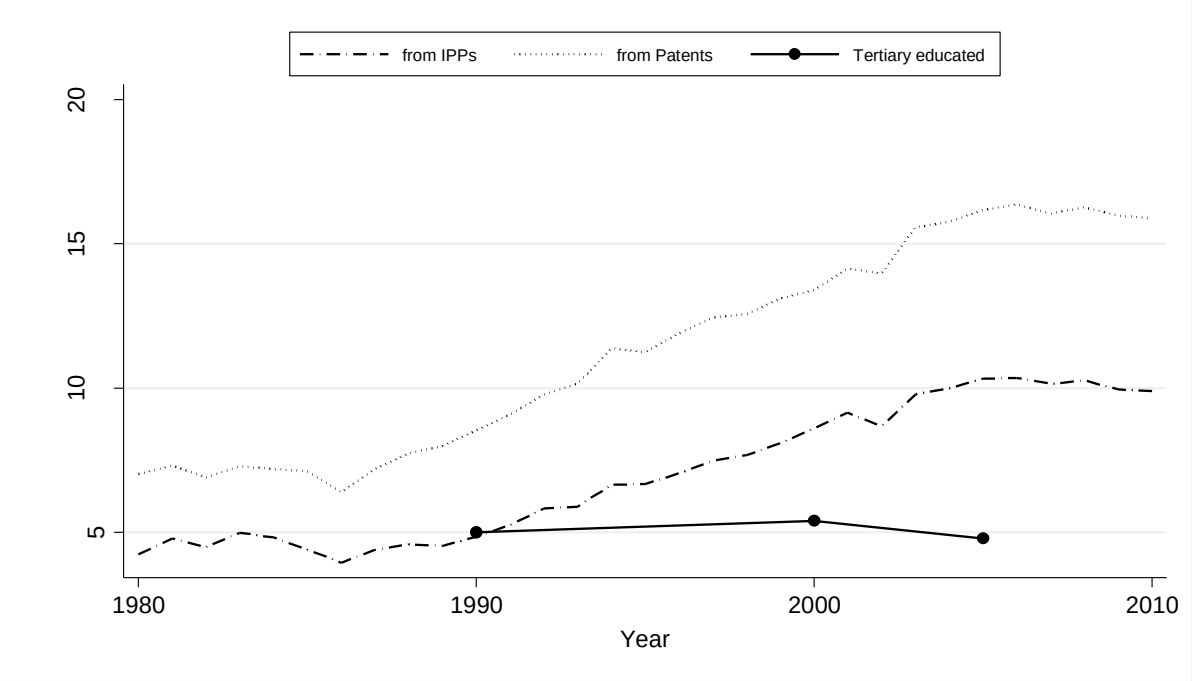
A first important finding is that one sees exceptionally high migration rates for inventors. To motivate this, the prior literature has estimated a global migration rate in 2000 for the population of age 15 and older of 2.4 percent. It has also established that the migration rate increases with migrants' skills; in particular, estimates suggest a 1.1 percent migration rate for the unskilled population, a 1.8 percent rate for the population with secondary education, and a 5.4 percent rate for the population with tertiary education (see subsection 3.2). The PCT-based inventor data, in turn, point to an inventor migration rate of 7.46 percent for a 10-year time window between 1991 and 2000, and 9.95 percent for the period 2001-2010, taking the skills bias in the propensity to migrate one step further.

Figure 2 depicts the evolution of the share of IPPs in PCT patent applications with migratory background for the whole world. As can be seen, the share of migrant IPPs has steadily increased over time. For comparison purposes, Figure 2 also depicts three data points corresponding to the migration rates of college graduates – as extracted from census data. Clearly, inventors' migration figures are notably larger – and significantly increasing over time. Finally, the dotted line depicts the share of patents containing at least one migrant inventor. Related studies have used this measure to compute the immigration rates of inventors as extracted from patent data (Wadhwa et al. 2007). However, this patent-level calculation includes inventions with multiple inventors as long as one inventor is a

non-citizen, so this estimate is an upper bound on the aggregate role of non-citizens. The remainder of this study thus computes figures based on the record-level calculation – unless otherwise stated.

For further information, Appendix 2 includes the total number of records and patents over time, and the number of, respectively, records and patents with migratory background.

Figure 2: Share of migrant inventors, 1980-2010



5.1. Migrant inventors from the perspective of receiving countries

Figure 3 depicts again the immigration rate of inventors for the whole world, alongside the same figures broken down for a selection of continents. The figure shows that North America stands out as seeing the highest shares of immigrant inventors relative to the continent's population of resident inventors, followed by Oceania and the Pacific, and Europe. These patterns and trends are in line with those observed for high-skilled migration more generally, whereby countries such as the US, Canada, Australia or New Zealand stand out as exhibiting the largest shares of immigrant workers, while European economies are lagging behind in attracting talent.[22]

Table 9 divides the data into two different time windows – 1991-2000 and 2001-2010, and compute immigration rates for both time windows, as a whole and broken down by continents, OECD membership, income level and size. Several interesting findings emerge. First, for the period 2001-2010, again North America and Oceania and the Pacific show the largest immigration rates. The general immigration rate in OECD countries stands at 10.26 percent – higher than for the non-OECD countries (6.13 percent). High income economies, according to the World Bank 2012 classification – also show, on average, large immigration rates during 2001-2010 (10.47%) as compared to upper and lower middle income economies (3.39% and 2.04%). At the same time, larger is the country – in terms of population – the lower is the immigration rate.

[22] See Bertoli et al. (2012) and Docquier and Rapoport (2009).

Figure 3: Share of immigrant inventors, by receiving continent 1985-2010

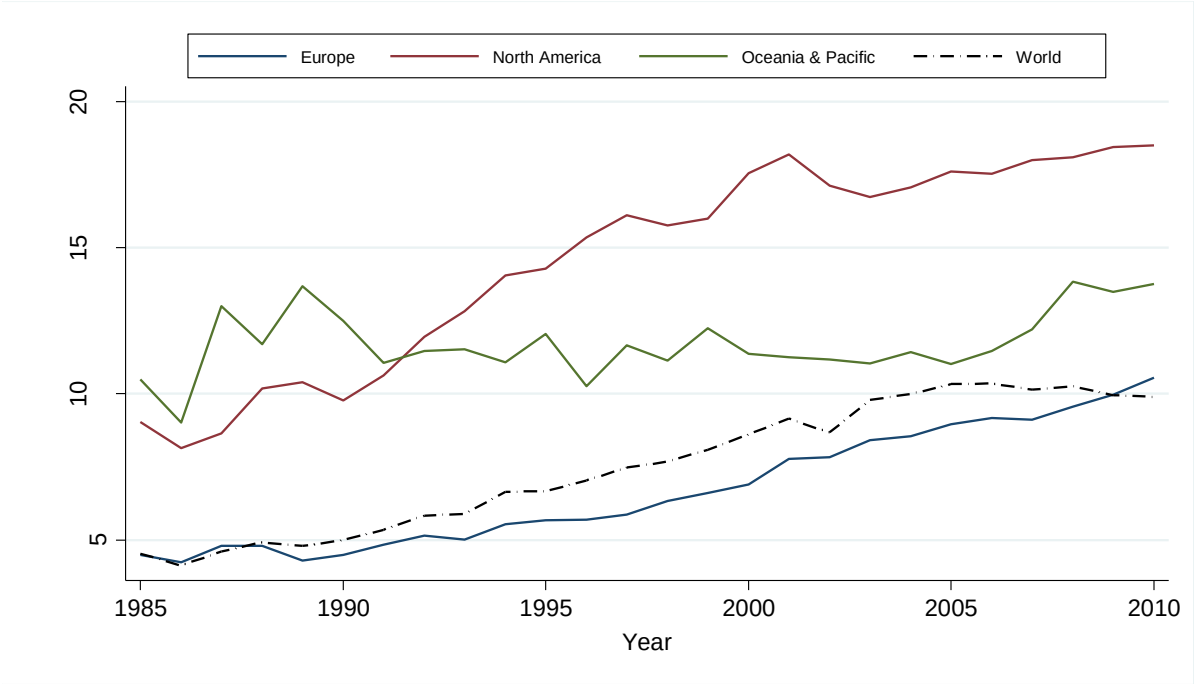


Table 9 also reveals that immigrant inventor stocks are highly concentrated from the receiving countries' perspective. For instance, during the period 2001-2010, 95.34 percent of immigrant inventors resided in an OECD country, and 97.7 percent of them lived in a high income economy. North America contributes the most to these figures. This can be clearly seen in Figure 4: 59 percent of immigrant inventor stocks resided in North America. However, a non-negligible 32 percent lived in Europe.

Table 9: Immigration rates of inventors, by receiving country group – 1991-2000 and 2001-2010

	Period 1991-2000		Period 2001-2010	
	Immigration rate	Concentration (percent)	Immigration rate	Concentration (percent)
Total	7.46		9.95	
Continent				
Africa	13.89	0.60	7.44	0.18
Asia	1.53	4.61	2.22	6.66
Europe	6.06	41.58	9.09	31.87
LAC	13.45	0.63	6.13	0.33
North America	15.67	48.90	17.76	59.30
Oceania & Pacific	11.45	3.69	12.07	1.67
OECD memb.				
no OECD	7.23	3.44	6.13	4.66
OECD	7.47	96.56	10.26	95.34
Income				
High income	7.57	98.13	10.47	97.70
Upper-middle income	4.18	1.63	3.39	2.01
Lower-middle income	4.32	0.20	2.04	0.26
Low income	30.86	0.04	23.23	0.02
Population				
Large	6.94	76.41	9.16	79.89
Upper-Middle	9.61	5.17	13.10	4.52
Lower-Middle	9.64	17.65	15.69	15.22
Small	25.36	0.77	17.23	0.37

Notes: Income groups according to the World Bank classification of 2012. Population groups are built as follows: Small (<2.5 mill.); Lower-Middle (>2.5 mill. & <15 mill.); Upper-Middle (>15 mill. & <25 mill.); and Large (>25 mill.).

Figure 4: Concentration of immigrants by continent, 2001-2010

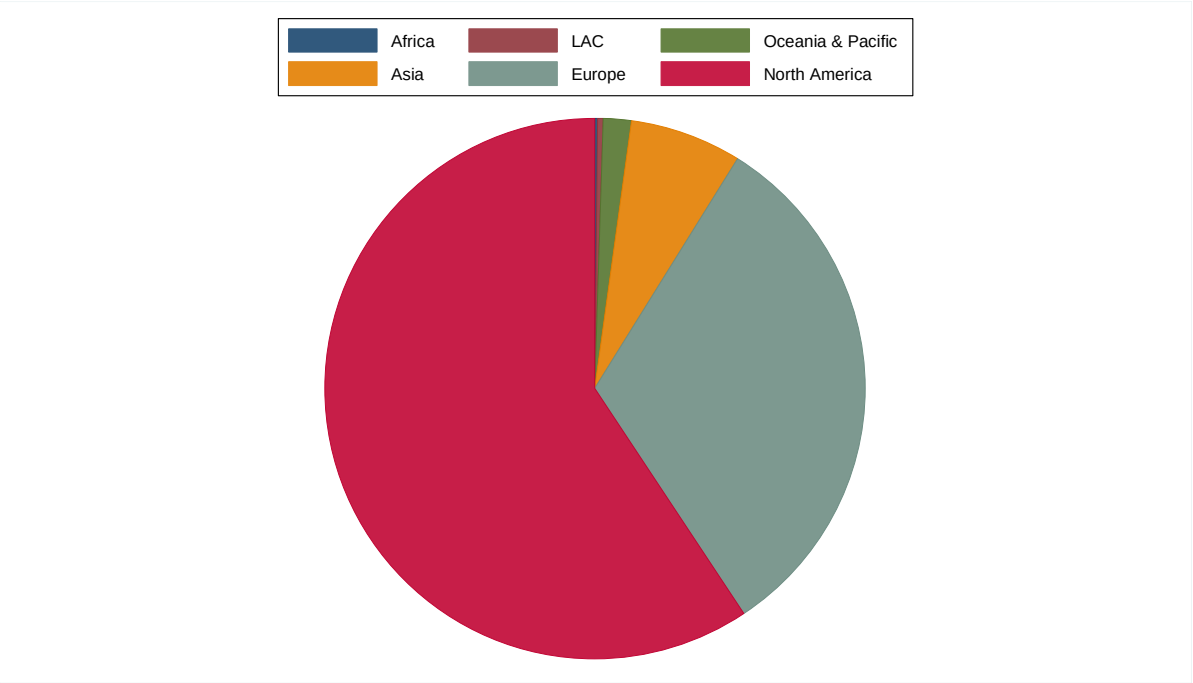


Figure 5, panel a, shows the inventor immigration rates for selected countries and confirms the former results.[23] In particular, Australia, Canada and especially the US stand out as the primary receiving countries relative to their population of inventors, while Europe as a whole lags behind. Japan and the Republic of Korea, in turn, are among the high income economies with the smallest inventor immigration rate (of less than 2 percent). Panel b of Figure 5 shows that Germany and France have consistently seen lower inventor immigration rates compared to the US, Australia or Canada. Of special interest is the UK, which has experienced a substantial increase in its share of immigrant inventors. Scandinavian economies also seem to have increased their share of immigrant inventors from the mid-2000s onwards.

[23] This study uses the list of countries, areas or territories used by the United Nations Statistics Division. See http://unstats.un.org/unsd/methods/m49/m49alpha.htm (accessed 24th August 2013) and also Appendix 8.

Figure 5: Share of immigrant inventors, 1990-2010

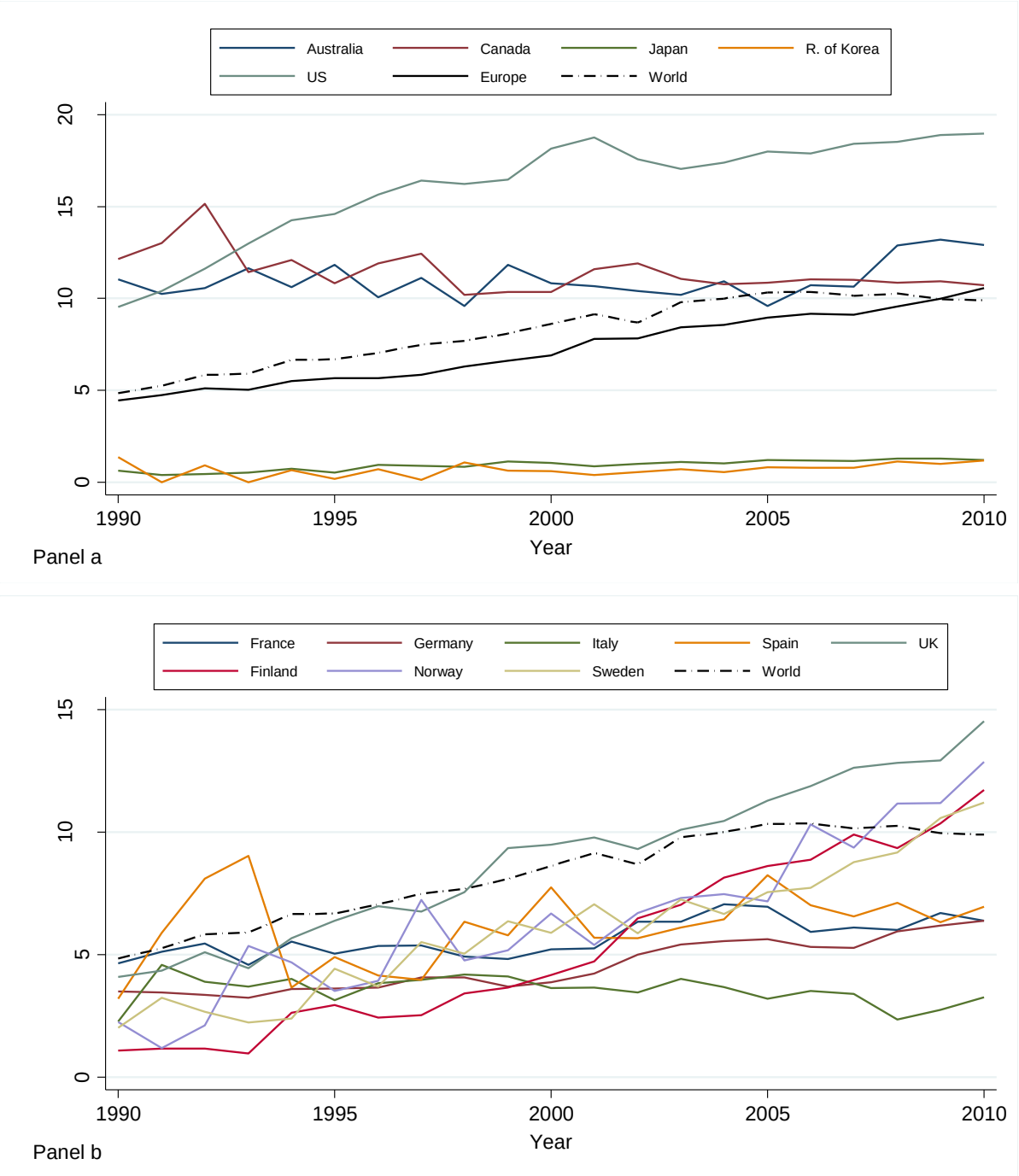


Figure 6 includes additional high income economies and depicts the immigration rates of inventors for the two separate time windows. The chart shows that relatively small countries see even larger immigration rates than the US – notably, Belgium (19%), Ireland (20%), Luxembourg (35%), and Switzerland (38%). Moreover, countries such as Switzerland, Luxemburg, the Netherlands, Austria, and the UK, as well as the Scandinavian economies, have considerably increased their immigration rates in the 2000s as compared to their figures in the 1990s.

Figure 6: Immigration rates of inventors, 1991-2000 and 2001-2010

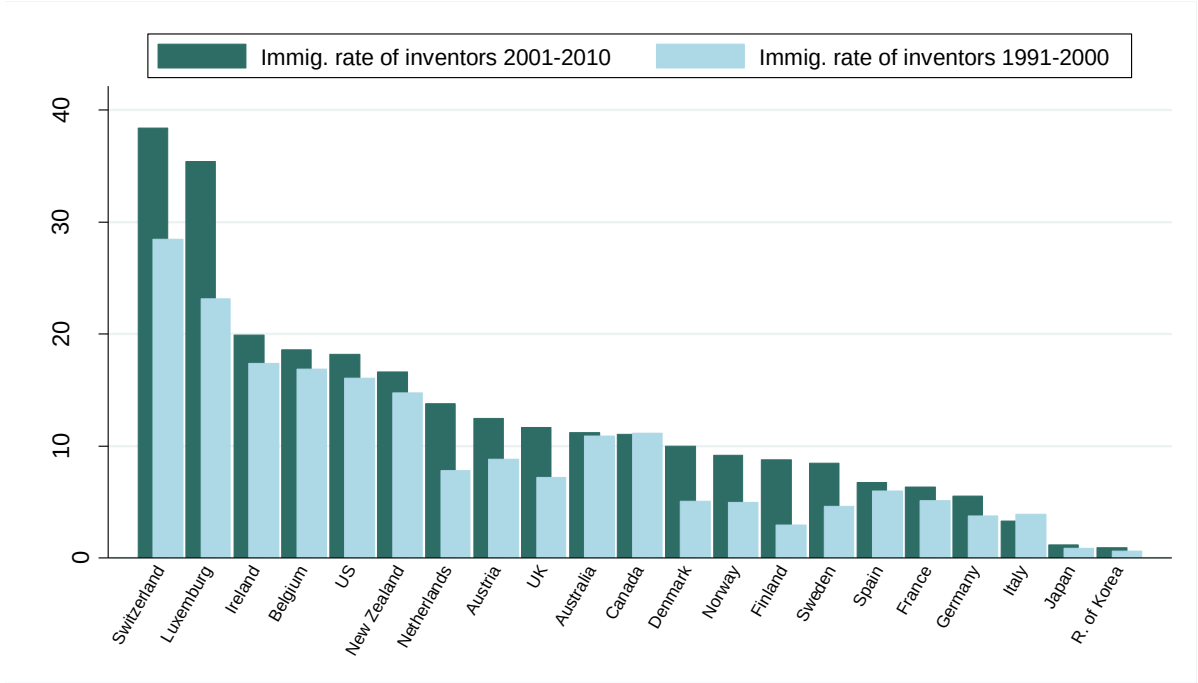


Table 10 lists the same immigration rates as shown in Figure 6, and compares them with immigration rates of college graduates using census 2000 data. It shows, first of all, a US immigration rate of college graduates far more in line with other large OECD countries, suggesting that the popularity of the US is somewhat unique to inventors. More generally, it is instructive to compute the ratio between inventor immigration rates and the immigration rate of college graduates. This ratio indicates to what extent inventor and tertiary educated immigration figures differ. The first thing to notice is that, with the exception of Finland (ratio 3.88 in favor of inventors), the ratios range from 0.34 (Australia) to 1.75 (Belgium). This suggests that for the majority of countries, the estimated inventor immigration rates emerging from the PCT data are broadly consistent with census data. At the same time, smaller countries, similar to the US, seem to be disproportionately popular among inventors compared to college graduates (ratio larger than 1.25). This is the case for Belgium, Denmark, Switzerland and, especially, Finland.

Table 10: Immigration rates of inventors and college graduates

	Imm. Rate 1991-2000	Imm. Rate 2001-2000	Imm. Rate College	Ratio (a)/(c)	Ratio (b)/(c)
	(a)	(b)	(c)	(d)	(e)
Australia	10.89	11.20	33.17	0.33	0.34
Austria	8.80	12.45	14.33	0.61	0.87
Belgium	16.89	18.56	10.61	1.59	1.75
Canada	11.16	11.03	25.84	0.43	0.43
Denmark	5.07	9.98	8.00	0.63	1.25
Finland	2.93	8.74	2.25	1.30	3.88
France	5.12	6.32	12.38	0.41	0.51
Germany	3.76	5.54	11.39	0.33	0.49
Ireland	17.38	19.89	18.07	0.96	1.10
Italy	3.88	3.27	6.11	0.64	0.54
Japan	0.87	1.15	1.05	0.83	1.09
Luxembourg	23.14	35.42	49.04	0.47	0.72
Netherlands	7.80	13.77	11.36	0.69	1.21
New Zealand	14.72	16.60	24.85	0.59	0.67
Norway	4.96	9.17	8.09	0.61	1.13
R. of Korea	0.59	0.90	0.88	0.67	1.02
Spain	5.95	6.72	6.38	0.93	1.05
Sweden	4.61	8.44	14.26	0.32	0.59
Switzerland	28.45	38.41	28.38	1.00	1.35
UK	7.17	11.62	16.00	0.45	0.73
US	16.07	18.18	13.86	1.16	1.31

Thus, the US, like many smaller receiving countries, performs well in attracting talent in relative terms – the share of inventors with migratory background among its residents. However, the US is performing especially well in absolute terms. The concentration of stocks of immigrant inventors in Europe, but especially North America, shown in Figure 4 is apparent when looking at individual countries. The US received 46.04 percent of all immigrant inventors in the period 1991-2000, and 57.17 percent in the period 2001-2010, see Table 11.[24]

Table 11: Concentration of immigrant inventors over total immigrants

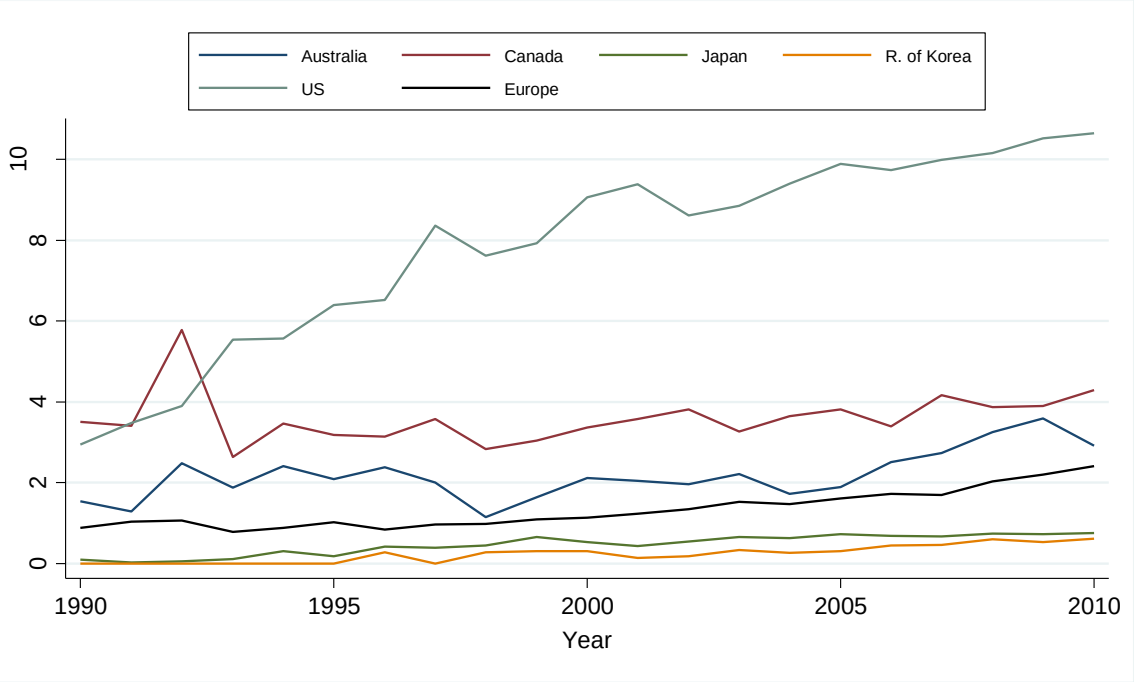
Period 1991-2000			Period 2001-2010		
Country	Immigrants	Share over total immigrants	Country	Immigrants	Share over total immigrants
US	31,358	46.04	US	194,609	57.17
Germany	6,887	10.11	Germany	25,341	7.44
UK	5,248	7.71	Switzerland	20,416	6.00
Switzerland	4,544	6.67	UK	15,758	4.63
France	2,909	4.27	Netherlands	9,665	2.84
Australia	2,051	3.01	France	9,540	2.80
Canada	1,943	2.85	Canada	7,257	2.13
Belgium	1,760	2.58	Singapore	6,720	1.97
Japan	1,376	2.02	Japan	6,715	1.97
Sweden	1,340	1.97	Belgium	5,042	1.48

The exceptional performance of the US in attracting talent can be further seen in Figure 7, which computes the immigration rate of inventors over time for a selection of countries but

[24] Note that the computed figures for the period 1991-2000 for the case of the US would be even more pronounced if we had complete coverage of nationality and residence information of this country during those years – which is actually "only" around 60 percent.

considers only immigrant inventors coming from non-high income countries – following the World Bank's income group classification of 2012. Interestingly, comparing Figures 5 and 7, the lead position of the US is more pronounced when only looking at non-high income countries immigrants. In other words, compared to other countries, the US appears to have been an especially popular destination for migrant inventors from low and middle income economies.

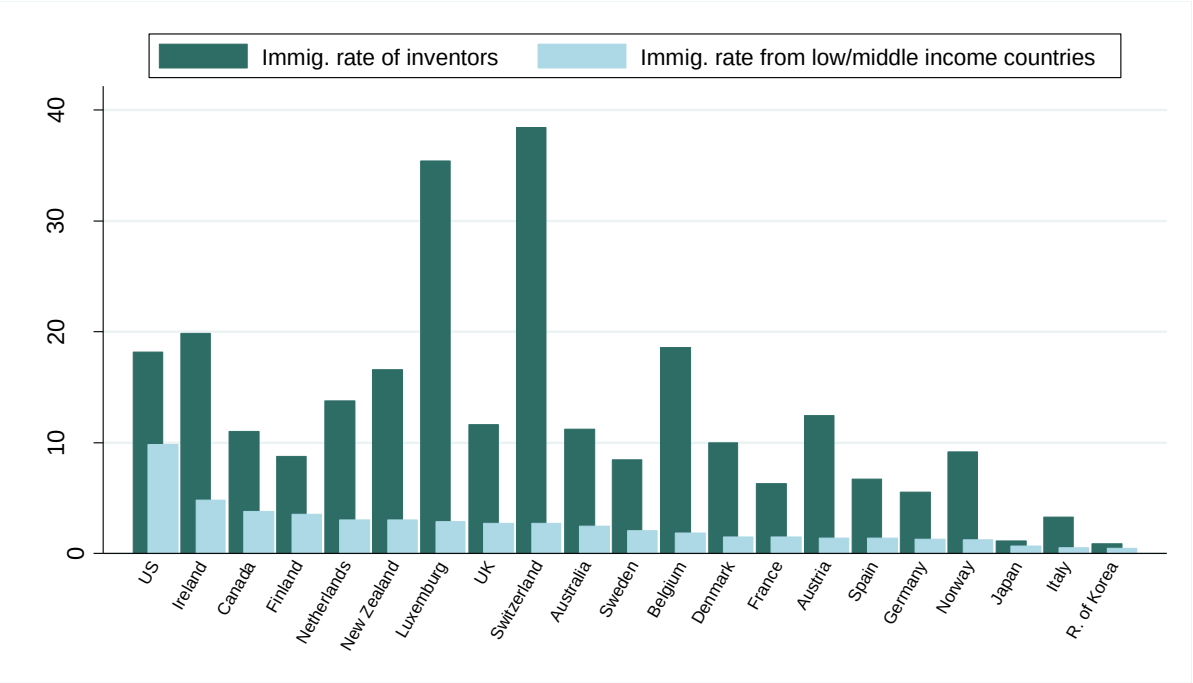
Figure 7: Share of immigrant inventors – immigrants from high income countries excluded, 1990-2010



Note: Income groups according to the World Bank classification of 2012.

Figure 8 depicts again the inventor immigration rate of inventors coming from non-high income economies only, plus the total immigration rate, for the period 2001-2010. It includes a larger list of receiving countries and compares the two immigration rates. Differently from before, the US leads the ranking of countries attracting inventors from non-high income economies– overcoming Switzerland, Luxemburg, Ireland and Belgium, where immigrants come largely from other European countries.

Figure 8: Immigration rates of inventors, total and South-North migration, 2001-2010



Note: Income groups according to the World Bank classification of 2012.

Table 12 shows that the concentration of immigrant stocks from non-high income countries in the US is overwhelming as compared to the remaining economies, confirming once more that the country is especially appealing for migrant inventors from low and middle income countries.

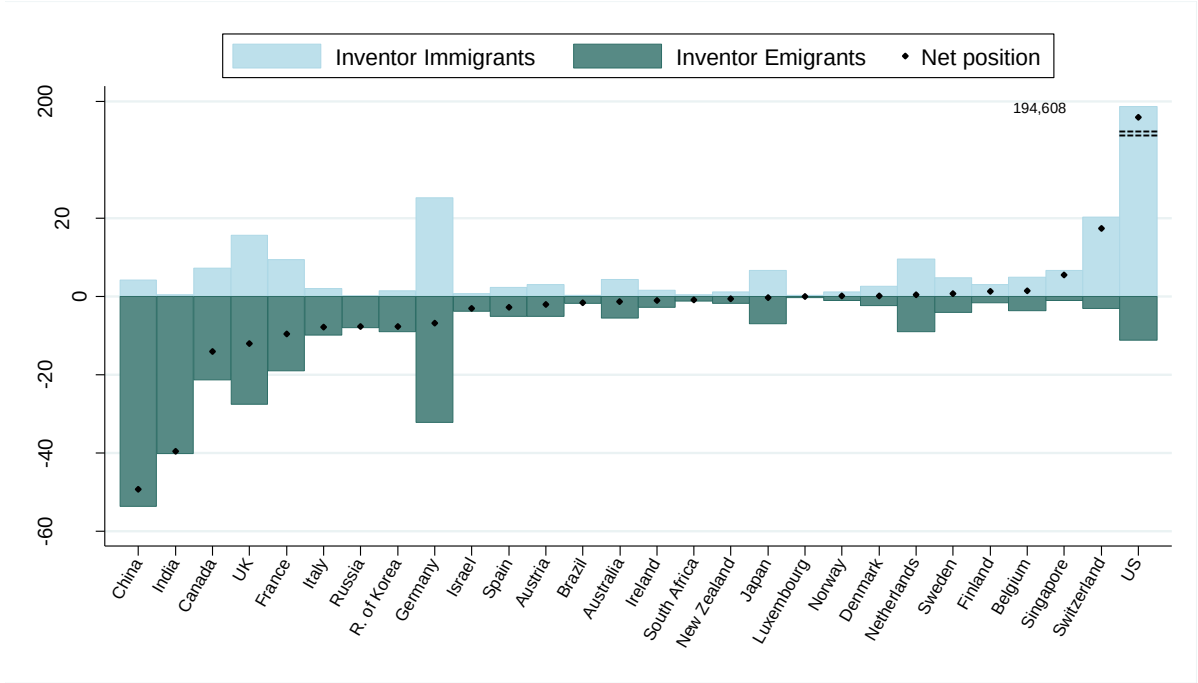
Table 12: Concentration of immigrant inventors from non-high income countries

South-North migrants, 1991-2000			South-North migrants, 2001-2010		
Country	Immigrants	Share over total immigrants	Country	Immigrants	Share over total immigrants
US	14,664	67.50	US	105,336	74.87
Germany	1,371	6.31	Germany	6,031	4.29
UK	1,277	5.88	Singapore	4,375	3.11
Japan	655	3.01	Japan	3,927	2.79
France	617	2.84	UK	3,729	2.65
Canada	573	2.64	Canada	2,503	1.78
Singapore	416	1.91	France	2,230	1.59
Australia	362	1.67	Netherlands	2,128	1.51
Sweden	307	1.41	Switzerland	1,451	1.03
Switzerland	279	1.28	Finland	1,265	0.90

Note: Income groups according to the World Bank classification of 2012.

It is also interesting to look at the difference between immigrant and emigrant stocks and order them according to their net position (see Figure 9 for the 2001-2010 period). There are fifteen times as many immigrant inventors in the US as there are US inventors residing abroad. Switzerland, Germany, and the UK also attract considerable numbers of inventors. Interestingly, though, Germany and the UK see more inventors emigrating than immigrating – which resembles the patterns shown in subsection 3.2 for tertiary educated persons and persons in high-skilled occupations. Canada and France similarly show a negative net inventor immigration position.

Figure 9: Net migration position, 2001-2010



Given the importance of the US as a receiving country, it is worth analyzing from where US inventor immigrants come. In absolute terms, for the period 2001-2010, China and India stand out – see the darker colors in Figure 10. These two countries alone account for more than 40 percent of the stock of immigrant inventors in the US. While the size of China and India matters, it is not the only explanation. In particular, as compared to their whole inventor emigrant stocks, China and India send a large share of all their emigrants to the US, along with Canada, some countries in the Caribbean as well as part of East Africa, and the two Koreas, among others (Figure 11).

Figure 10: Migrants to the US – absolute numbers, 2001-2010

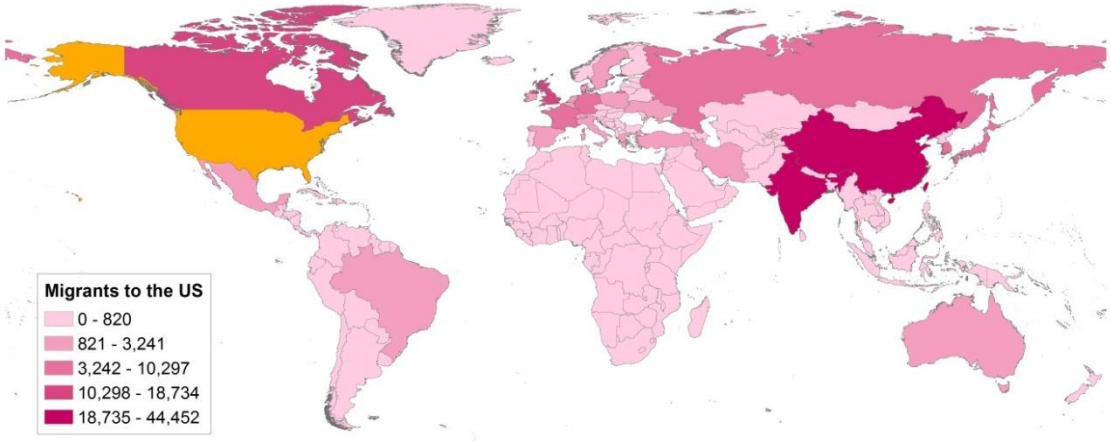


Figure 11: Migrants to the US – as shares of countries' emigrant stocks, 2001-2010

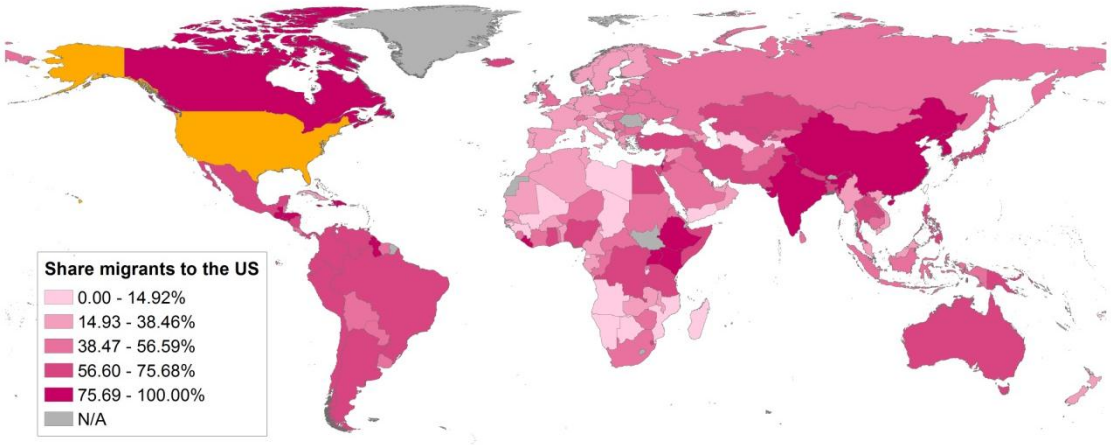


Figure 12 extends the analysis of immigrant origins to a larger set of receiving countries. In addition to the US, it includes other OECD countries for comparison purposes (Figures 12.a, 12.b and 12.c). Finally, Figure 12.d analyzes the so-called BRICS countries – namely, Brazil, Russia, India, China, and South Africa; it also includes Singapore – often seen as a regional hub attracting high-skilled talents. Countries seem to have an idiosyncratic distribution of origins; at the most, distributions reflect geographical proximity and shared historical, cultural, and language roots. It is worth to point out the case of Finland which, more than other high income European countries, relies on middle income countries as origins of immigrant inventors – especially for the period 2001-2010. Thus, China leads the Finnish ranking and other middle income countries also feature prominently – including, Russia, India and Romania. Like in the US, specific demands of firms play an important role in explaining immigration patterns in Finland (Kerr 2013). Moreover, Finland has experienced the biggest increase in immigration rates of inventors between the 1991-2000 and 2001-2010 periods among the countries included in Table 10.

Figure 12: Shares of most popular origin countries, by selected destination countries
Figure 12.a:

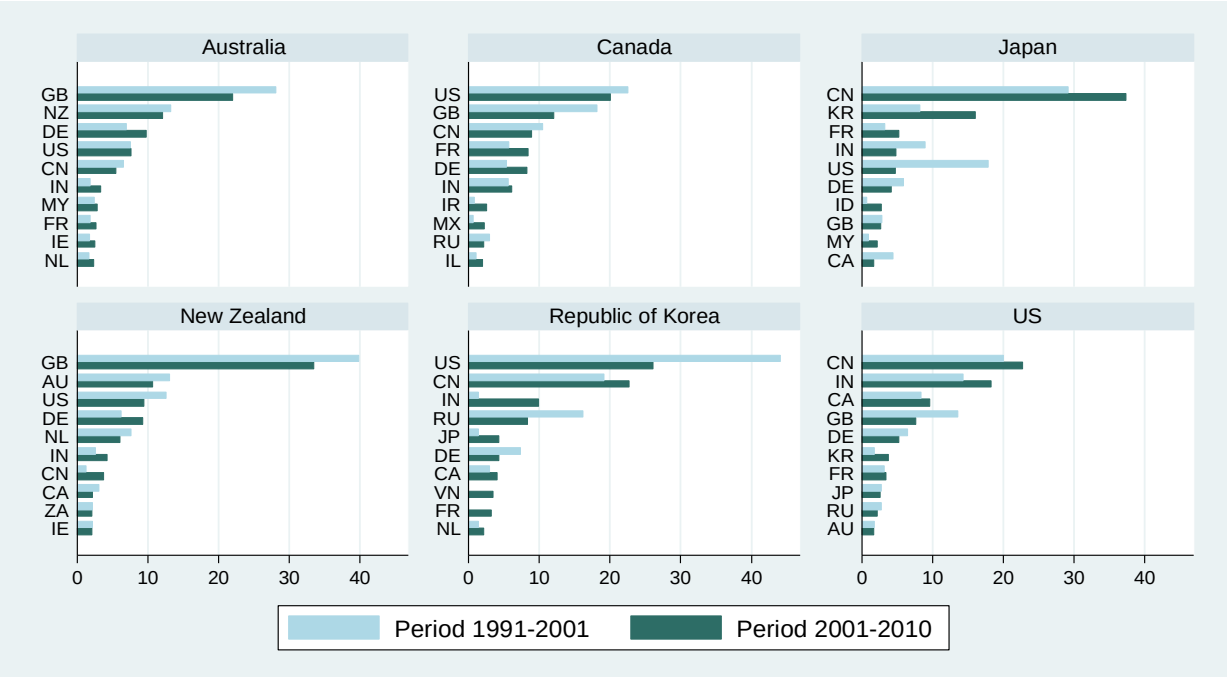


Figure 12.b:

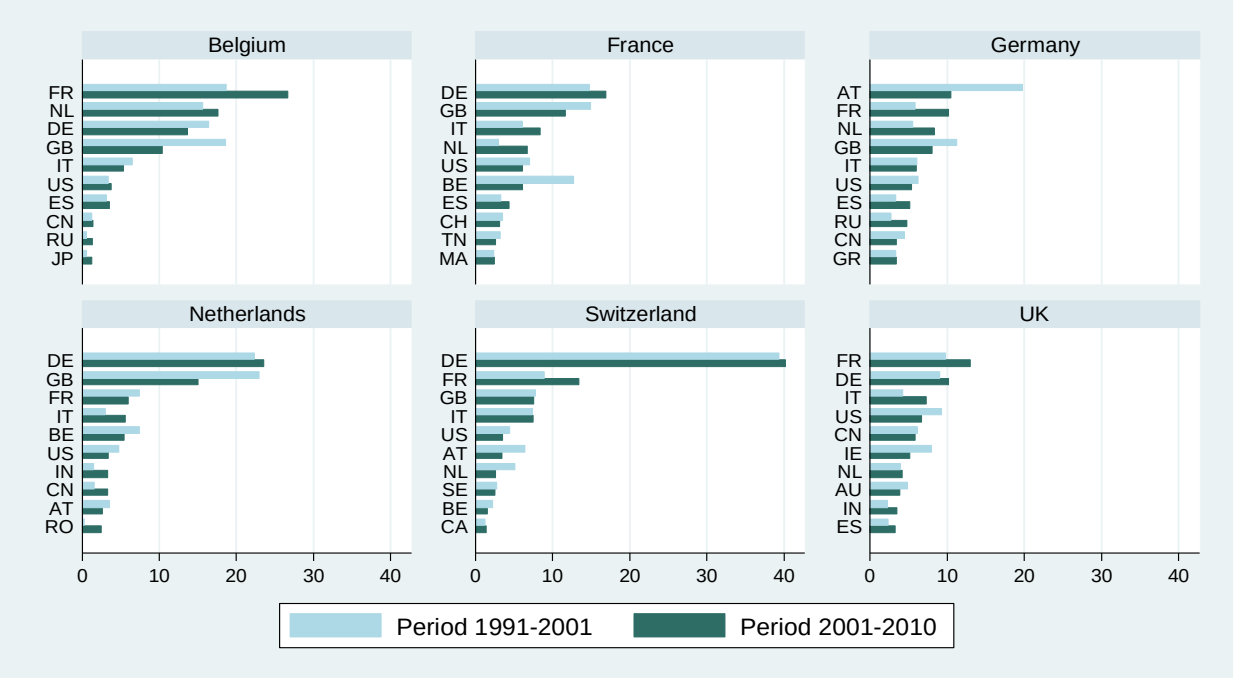


Figure 12.c:

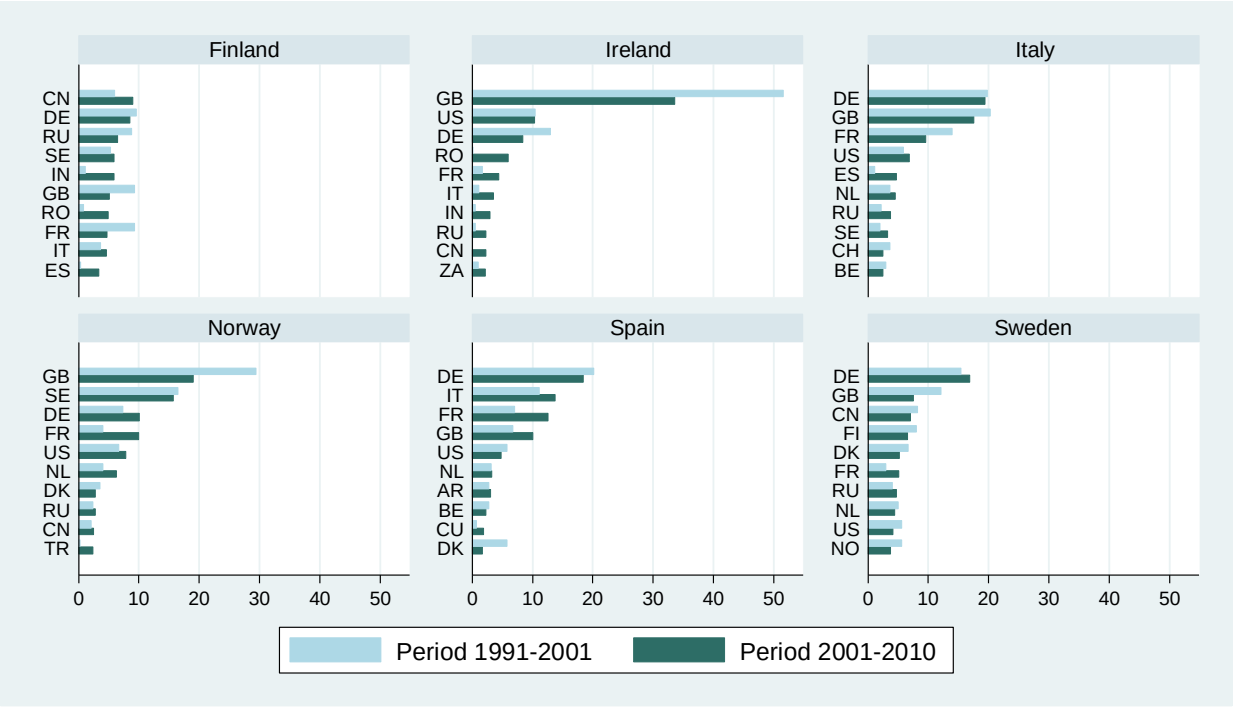
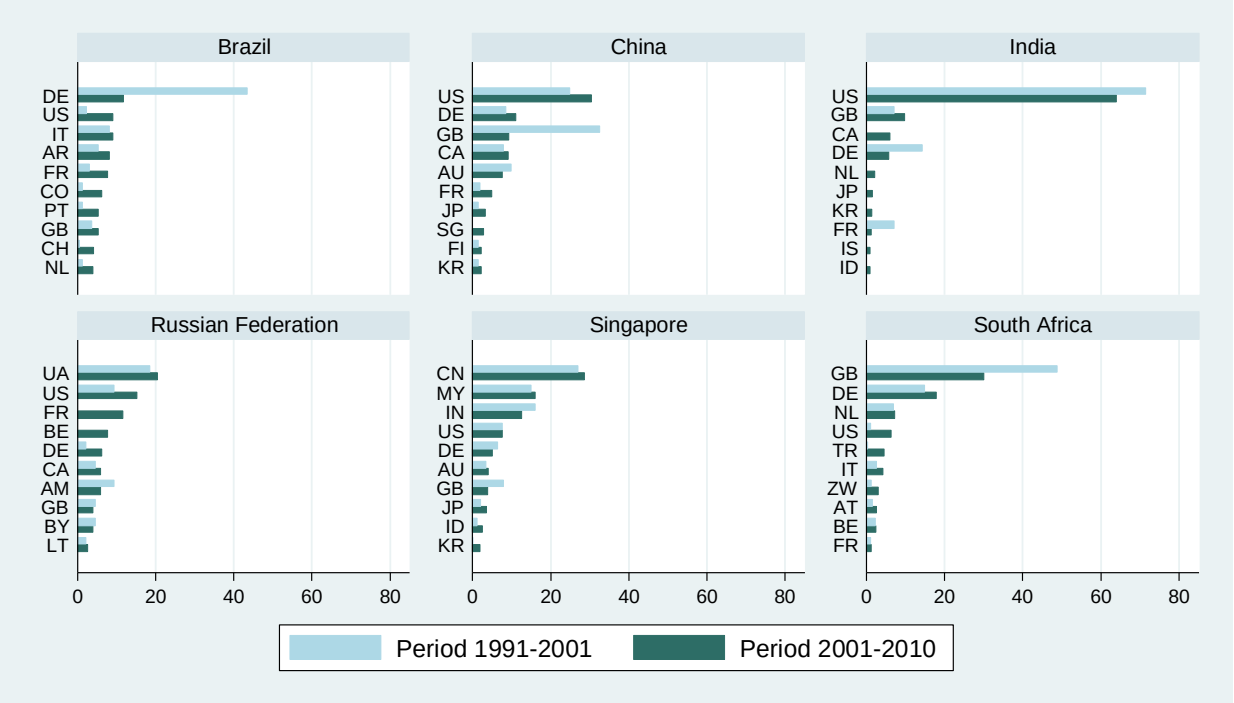


Figure 12.d:



Note: Country codes in the vertical axes are AM: Armenia, AR: Argentina, AT: Austria, AU: Australia, BE: Belgium, BY: Belarus, CA: Canada, CH: Switzerland, CN: China, CO: Colombia, CU: Cuba, DE: Germany, DK: Denmark, ES: Spain, FI: Finland, FR: France, GB: United Kingdom, GR: Greece, ID: Indonesia, IE: Ireland, IL: Israel, IN: India, IR: Iran, IS: Iceland, IT: Italy, JP: Japan, KR: Republic of Korea, LT: Lithuania, MA: Morocco, MX: Mexico, MY: Malaysia, NL: the Netherlands, NO: Norway, NZ: New Zealand, PT: Portugal, RO: Romania, RU: Russian Federation, SE: Sweden, SG: Singapore, TN: Tunisia, TR: Turkey, UA: Ukraine, US: United States, VN: Viet Nam, ZA: South Africa, and ZW: Zimbabwe.

More generally, inventor immigration shares do not only differ across countries, but also within countries across different applicants. For example, Figure 13 depicts the immigration shares for the largest PCT applicants from the US. Aside from the two educational institutions in the list that rank high in terms of foreign talent, applicants in sectors such as semiconductors, computing, or networking equipment, show above-average immigration rates (higher than 18.18%). Meanwhile, applicants in sectors such as aerospace, defense, energy exhibit lower immigration shares of 10 percent or less. Figure 14 presents similar information for other large receiving countries – namely, Germany, Switzerland, the UK and France.

Figure 13: Share of foreigners in top-25 PCT applicants from the US

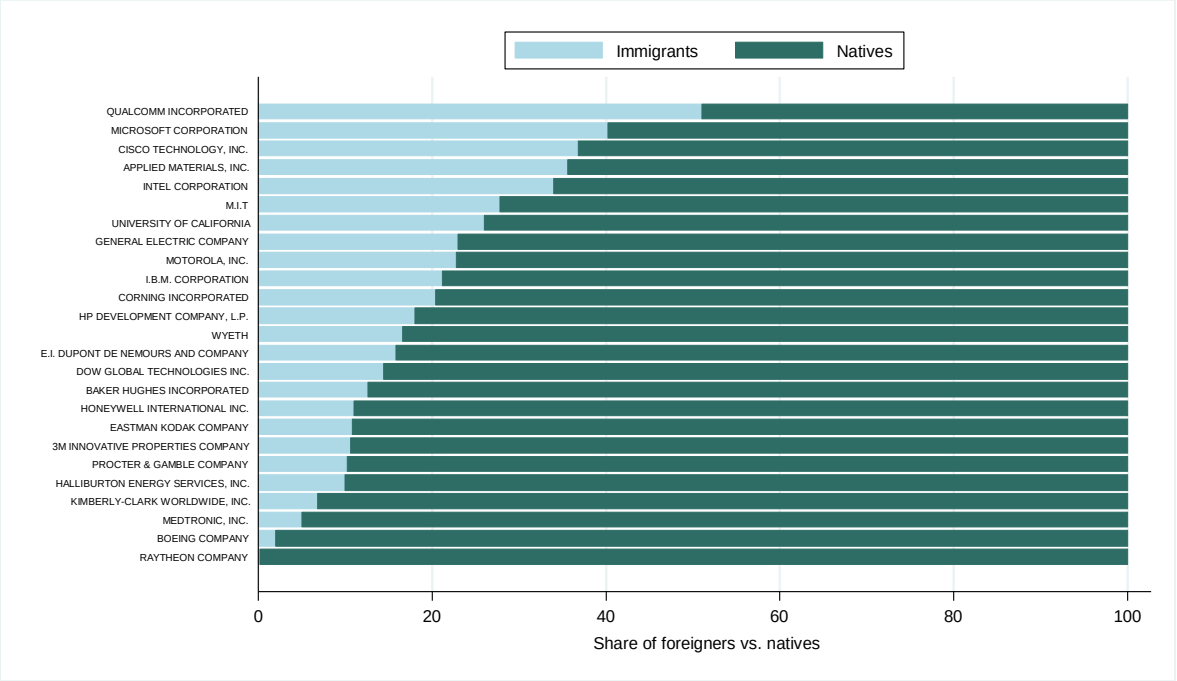
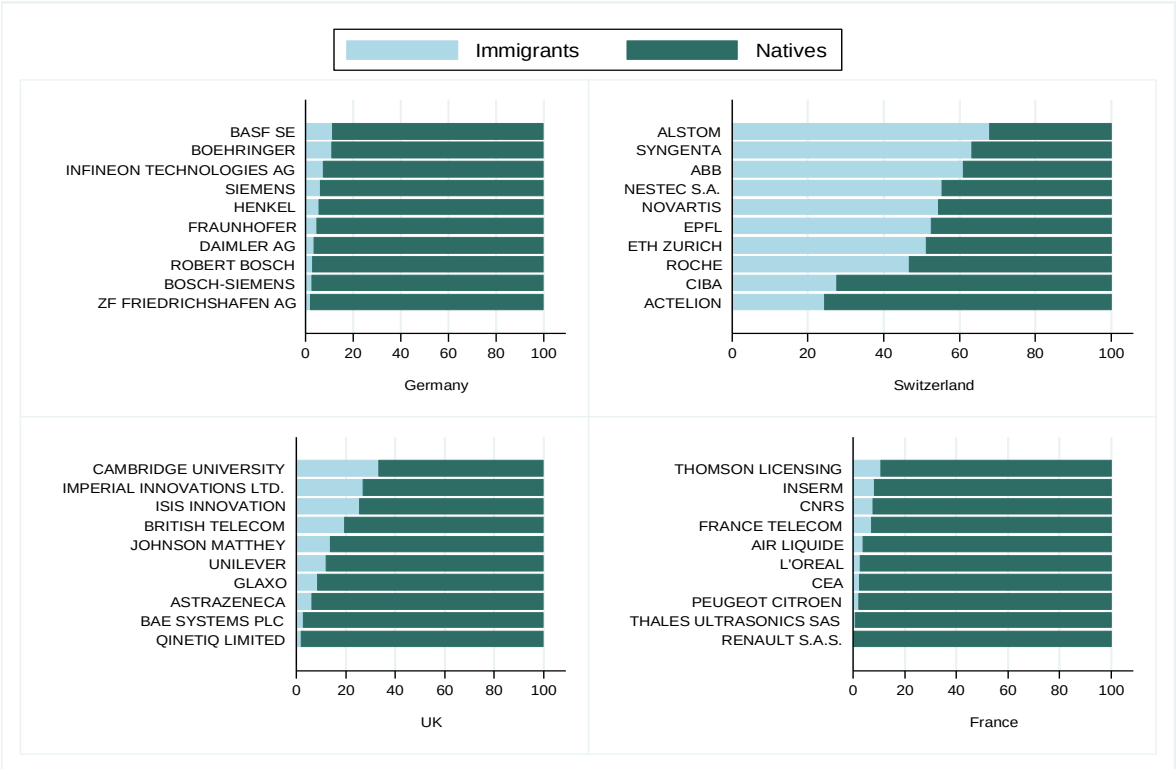


Figure 14: Share of foreigners in top-10 PCT applicants from Germany, Switzerland, the UK and France



One interesting aspect that is apparent from the previous figures is the role of universities and public research centers in recruiting talents from abroad. The top patenting universities and public research centers feature some of the largest immigration rates amongst the top PCT applicants. This is the case of the University of California and the Massachusetts Institute of Technology in the US; the *École Polytechnique Fédérale de Lausanne* (EPFL) and *Eidgenössische Technische Hochschule Zürich* (ETH ZURICH), in Switzerland; Cambridge University, Imperial Innovations (Imperial College London), and Isis Innovation (Oxford University) in the UK; and the *Institut national de la santé et de la recherche*

médicale (INSERIM) and the *Centre national de la recherche scientifique* (CNRS) in France. Even if anecdotal, it seems reasonable to argue that universities and public research organizations act as privileged "points of entry" for high-skilled workers from abroad. This is relevant for evaluating the welfare-impact of skilled migration: if the brain drain occurs at the education stage – particularly, at the post-graduate education stage – sending countries may have higher chances to turn the brain drain into a brain gain, as future returnees require valuable skills that they can take home. Moreover, if academics are more likely to move back to their origin countries, international knowledge spillovers are more likely to occur.

Figure 15 explores this possibility by depicting the immigration rates of inventors for a selection of destination countries in 2001-2010 separately for academic and corporate inventors. As can be seen, university immigration rates are systematically larger in 15 out of 20 of the countries included, confirming that universities and research organizations constitute privileged points of entry for foreign inventors. In selected countries, the academic immigration rate is considerably higher than the corporate immigration rate – in particular, in Japan, the UK, Sweden, Norway, the Republic of Korea, Australia, Canada and the US. Only Belgium, the Netherlands, Finland, Spain and Italy do not show larger immigration rates for academics than corporate inventors. Interestingly, when accounting for inventors coming only from low and middle income economies, the differences between immigration rates are even larger, except for the case of New Zealand (see Figure 16).

Figure 15: Immigration rates of inventors. University vs. corporate inventors, 2001-2010

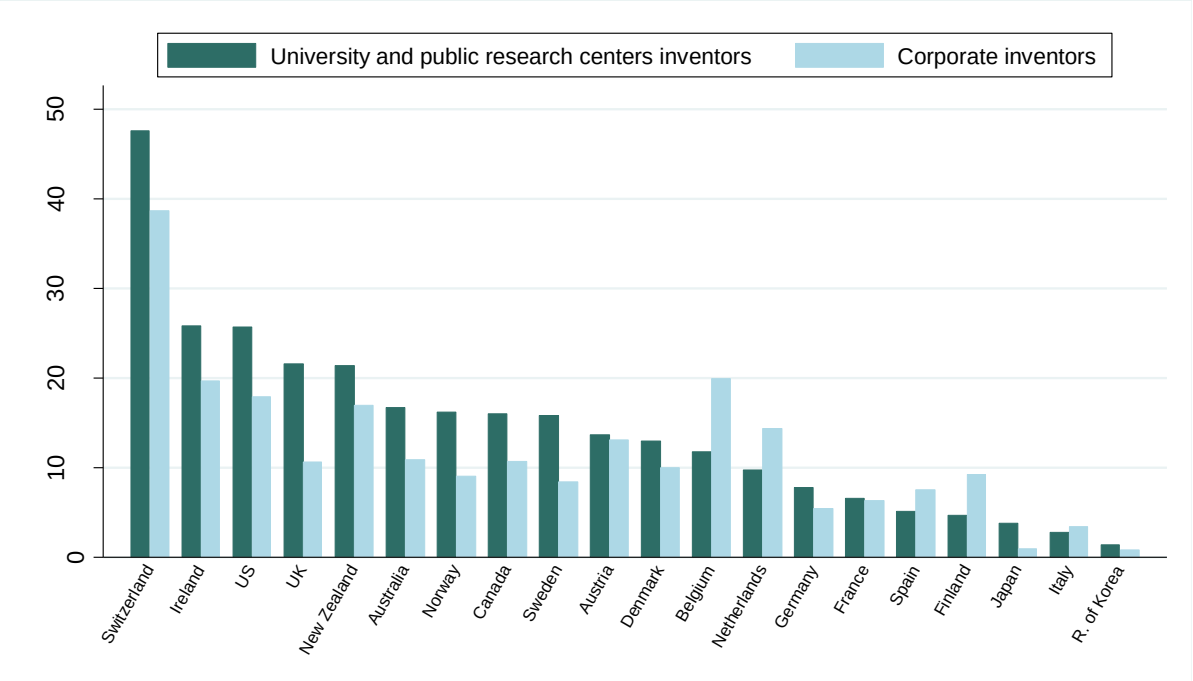
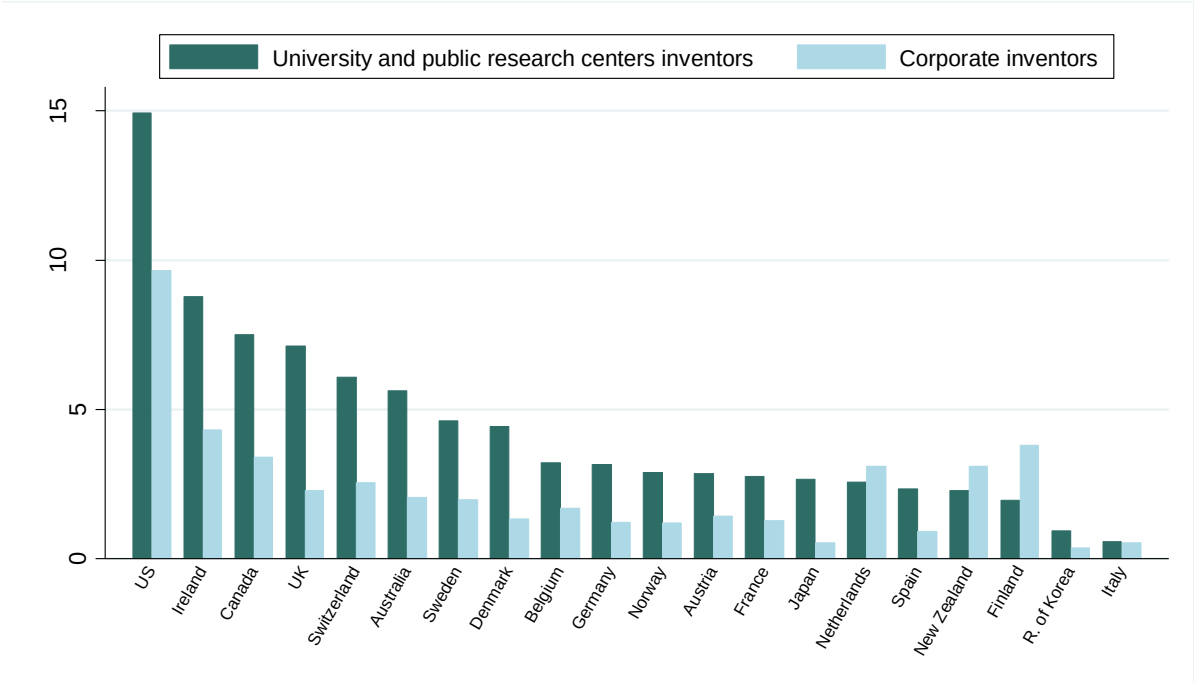


Figure 16: Immigration rates of inventors from low and middle income economies. University vs. corporate inventors, 2001-2010



Finally, PCT-based inventor immigration data can offer a perspective on an ongoing debate in both the academic literature and journalistic discussions on the extent of foreign researchers' contribution to scientific advancement and innovation. In the US, some scholars remain skeptical on immigrants' contribution to overall economic performance (above all, Borjas, 1999). Others have found strong evidence for a positive and important role played by skilled immigrants on receiving countries' economic development.

In order to investigate the contribution of immigrants in their host country economy, it is insightful to explore the number of citations received by PCT applications with and without migrating inventors. The economic literature has used the number of citations as a measure of patent's underlying quality. Table 13 presents the share of all patents with at least one listed inventor with migratory background and compares it with the share of inventors with migratory background listed in breakthrough patents – defined as the top 5% of patents in terms of citations received in the following 5 years after application. As can be seen, the proportion of immigrants is systematically larger among breakthrough inventions than among the whole universe of PCT patents. This supports that immigrants disproportionately contribute to their host country productivity – measured here by citations received. Note that the differences are statistically significant in most of the cases (see the last column in Table 13) except for the Netherlands, Austria, Ireland and the Republic of Korea.[25]

[25] In unreported results we repeat this same analysis but only with PCT patent application filed between 2001 and 2010. The results are confirmed, and even strengthened, since the differences in shares turn out to be statistically significant for all countries listed in Table 13.

Table 13: Share of immigrants in highly-cited patents

	% foreigners in all patents	% foreigners in 5% most-cited patents	Significance difference
US	18.17	22.53	t-statistic=24.55*** *p-value=0.000*
Germany	12.18	19.90	t-statistic=27.65*** *p-value=0.000*
Switzerland	35.27	44.06	t-statistic=9.38*** *p-value=0.000*
UK	14.74	21.16	t-statistic=13.11*** *p-value=0.000*
Netherlands	18.40	18.95	t-statistic=0.87 *p-value= 0.384*
France	11.45	17.56	t-statistic=13.57*** *p-value=0.000*
Canada	19.49	25.09	t-statistic=6.68*** *p-value=0.000*
Singapore	52.88	62.46	t-statistic=3.48*** *p-value=0.001*
Japan	3.25	4.46	t-statistic=9.89*** *p-value=0.000*
Belgium	22.89	35.61	t-statistic=8.17*** *p-value=0.000*
Sweden	11.08	18.29	t-statistic=12.42*** *p-value=0.000*
Australia	16.28	24.81	t-statistic=9.11*** *p-value=0.000*
China	4.31	9.31	t-statistic=15.42*** *p-value=0.000*
Austria	12.07	13.88	t-statistic=1.51 *p-value= 0.129*
Finland	15.67	17.61	t-statistic=2.05** *p-value= 0.040*
Denmark	14.33	23.24	t-statistic=7.91*** *p-value=0.000*
Spain	10.10	15.74	t-statistic=5.32*** *p-value=0.000*
Italy	4.45	7.82	t-statistic=7.74*** *p-value=0.000*
Ireland	30.97	33.70	t-statistic=0.95 *p-value= 0.343*
R. of Korea	2.56	2.68	t-statistic=0.48 *p-value= 0.631*

Note: ***, **, and * indicates significance at 1, 5, and 10 percent levels respectively.

5.2. The perspective of sending countries – the Brain Drain

This section turns to inventor emigration patterns and trends. As pointed out in subsection 3.2, the prior literature has estimated a 5.4 percent global migration rate for tertiary educated workers. However, this figure hides considerable variation in emigration propensities across continents: in high income countries the emigration rate stood at 3.8 percent, compared to

6.3-6.9 percent in low and middle income countries. It was much higher for least developed countries (13.1%) and for small island developing states (42.4%).[26]

These differences turn out to be even more marked when looking at inventor data. The global share of IPPs with migratory background stood at 7.46 percent from 1991 to 2000, and at 9.95 percent from 2001 to 2010 – see Table 14. However, the inventor emigration rate of high income countries for these two time periods only stood at 4.99 percent and 5.92 percent, respectively. It was much higher for low, lower-middle and upper-middle income countries – standing for the period 2001-2010 at 87.56 percent, 53.07 percent, and 30.30 percent, respectively.[27] Notwithstanding higher emigration shares in poorer countries, almost 58.9 percent of inventor migrants originated in high income countries in 2001-2010, where the inventor population is much higher. Meanwhile, middle income countries account for about 40.5 percent of all the stock of emigrants. Differences also exist between OECD members and non-members – with the former showing lower emigration rates than the latter. Finally, more populous countries show lower emigration rates, but at the same time, they account for nearly 80 percent of all the stock of emigrant IPPs in the period 2001-2010.

Large differences emerge when computing emigration rates of inventors separately by continent. As expected – and as it is found for the case of college educated individuals – the LAC region and, especially, the Africa region suffer the most severe brain drain of inventors, with ratios between 32 and 42 percent in both periods. Meanwhile, the other continents exhibit emigration rates in the range of 10-13 percent, with the exception of North America with a 3 percent rate. Figure 17 further depicts the evolution of emigration rates both for the world and for individual continents. It confirms that Africa as well as the LAC region by far exhibit the highest emigration rates. In 2010, almost half of all African inventors lived outside their home countries.

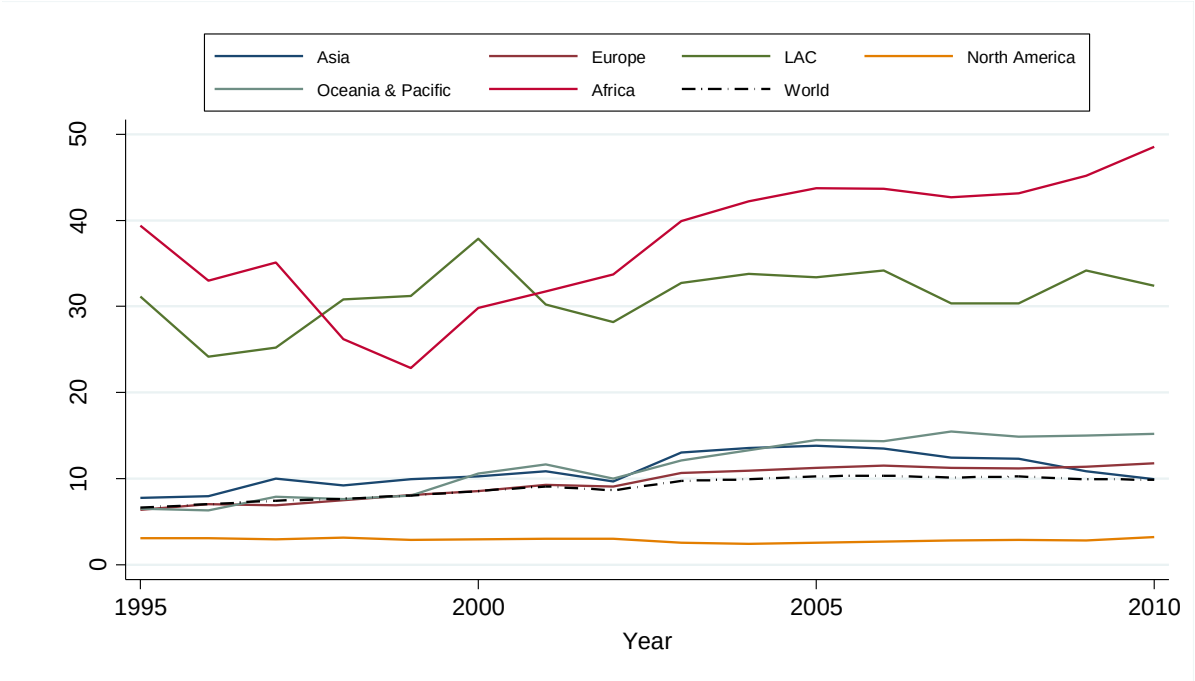
[26] As extracted from 2000 census data (Docquier and Marfouk 2006; Docquier et al. 2009).
[27] At first reading, it may not be entirely obvious why the global migration share increases by 2.48 percentage points, but the emigration rate of high income countries rises by only 1.07 percentage points and that of low and middle income county falls by 5.33 percentage points. The underlying reason is that low and middle income countries account for a larger share of the inventor population in the 2001-2010 period, giving greater weight to the higher emigration rate of those countries. The main reason for the falling emigration rate of low and middle income countries is the falling inventor emigration rate of China, which, in turn, is due to China's inventor population growing substantially faster than the number of emigrating inventors.

Table 14: Emigration rates of inventors, by country group – 1991-2000 and 2001-2010

	Period 1991-2000		Period 2001-2010	
	Emigration rate (percent)	Concentration (percent)	Emigration rate (percent)	Concentration (percent)
Total	7.46		9.95	
Continent				
Africa	31.59	2.00	42.12	1.76
Asia	9.08	30.19	11.93	40.74
Europe	7.16	53.30	10.94	43.19
LAC	32.11	2.24	32.19	2.53
North America	2.96	9.60	2.78	9.57
Oceania & Pacific	7.64	2.68	13.77	2.21
OECD memb.				
no OECD	40.21	32.03	35.27	41.44
OECD	4.99	67.97	5.93	58.56
Income				
High income	4.99	68.57	5.92	58.90
Upper-middle income	34.70	20.93	30.30	25.94
Lower-middle income	68.70	9.98	53.07	14.55
Low income	81.07	0.51	87.56	0.62
Population				
Large	6.94	76.41	9.16	79.89
Upper-Middle	9.61	5.17	13.10	4.52
Lower-Middle	9.64	17.65	15.69	15.22
Small	25.36	0.77	17.23	0.37

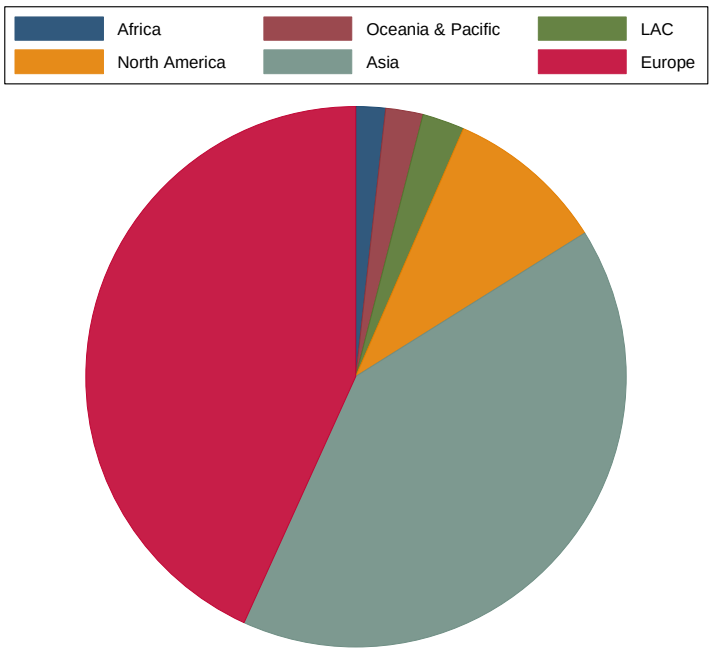
Note: Income groups according to the World Bank classification of 2012. Population groups are built as follows: Small (<2.5 mill.); Lower-Middle (>2.5 mill. & <15 mill.); Upper-Middle (>15 mill. & <25 mill.); and Large (>25 mill.).

Figure 17: Emigration rates, 1995-2010



Like immigration stocks, emigration is highly concentrated in absolute numbers. However, differently from the former, Europe and Asia together account for more than 80 percent of inventor emigrant stocks for the period 2001-2010 (Figure 18), with about 40 percent of the emigrants coming from each continent.[28]

Figure 18: Concentration of emigrants by continent, 2001-2010



[28] The stock of emigrants from Asian countries increased considerably from the period 1991-2000 – from 30.19 percent to 40.74 percent (see Table 14).

Table 15 lists emigration stocks for individual countries – and the shares over total emigrants. Like for the case of high-skilled occupations as extracted from 2000 census data (see subsection 3.2), the UK, China, Germany and India led the ranking in terms of emigrant stocks in 1991-2000. As can be seen, in 2001-2010 China and India took the lead and, jointly with some of the largest European countries, accounted for the large majority of emigrant inventors. However, compared to immigration patterns, emigrant inventors are, by and large, more evenly distributed across countries – for the period 2001-2010, the US alone receives around 57 percent of all immigrant inventors; conversely, up to six countries (China, India, Germany, the UK, Canada and France) host 57 percent of all emigrant inventors.

Table 15: Share of emigrant inventors over total emigrants, by country

Total emigrants, 1991-2000			Total emigrants, 2001-2010		
Country	Emigrants	Share over total emigrants	Country	Emigrants	Share over total emigrants
UK	8,930	13.11	China	53,610	15.75
China	8,206	12.05	India	40,097	11.78
Germany	7,216	10.60	Germany	32,158	9.45
India	5,193	7.63	UK	27,746	8.15
France	3,350	4.92	Canada	21,315	6.26
Canada	3,286	4.83	France	19,123	5.62
US	3,205	4.71	US	11,131	3.27
Italy	2,068	3.04	Italy	9,820	2.88
Austria	1,993	2.93	Netherlands	9,132	2.68
Netherlands	1,986	2.92	R. of Korea	9,127	2.68

In the 2001-2010 period, China and India alone account for almost 28 percent of all emigrant inventors. Where do Chinese and Indian inventors go? In large part, they go to the US, as can be seen in Figure 19. For the sake of comparison: Japan, the second major destination of Indian and Chinese inventors, accounts for only 3.5 percent of the Indian and Chinese inventors that go to the US. In addition, Chinese and Indian inventors alone account for around 42 percent of all immigrants in the US (see Figure 20). Similarly, Japan, Singapore and the Republic of Korea have immigrant stocks of inventors from China and India larger than 30 percent (see Figure 20).

Figure 19: Emigrants from India and China – absolute numbers, 2001-2010

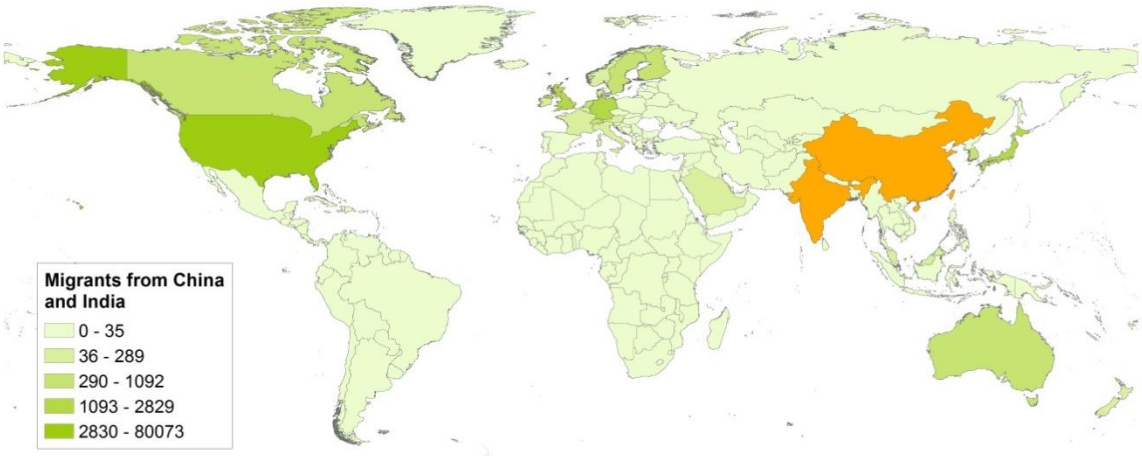


Figure 20: Emigrants from India and China – as shares of total immigrants, 2001-2010

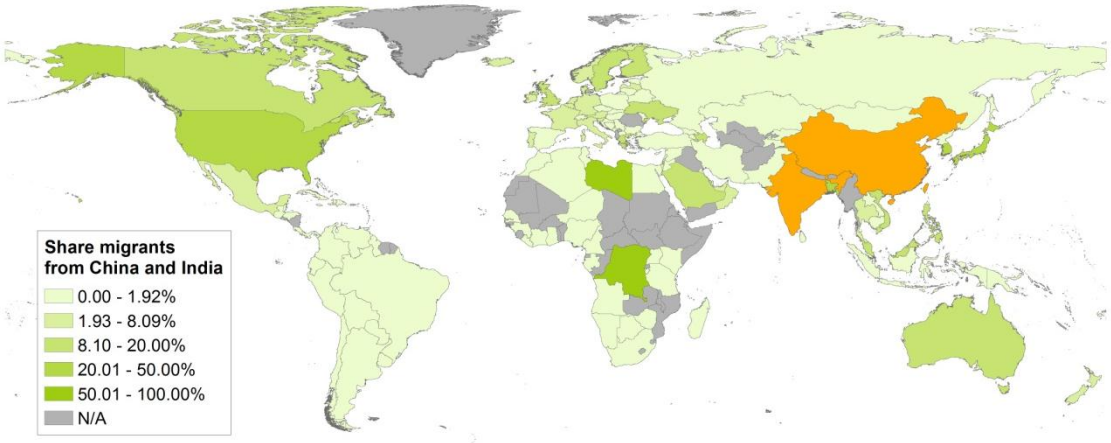


Figure 21 extends this analysis to a larger number of sending countries – aside from China and India. With almost no exception among the selected countries, the US is overwhelmingly the primary destination of emigrant stocks for most of the countries. For some countries, like China and India, but also Canada, Russia and the UK, the dominant position of the US is highly pronounced.

Figure 21: Share of most popular destination countries, by selected origin countries
Figure 21.a:

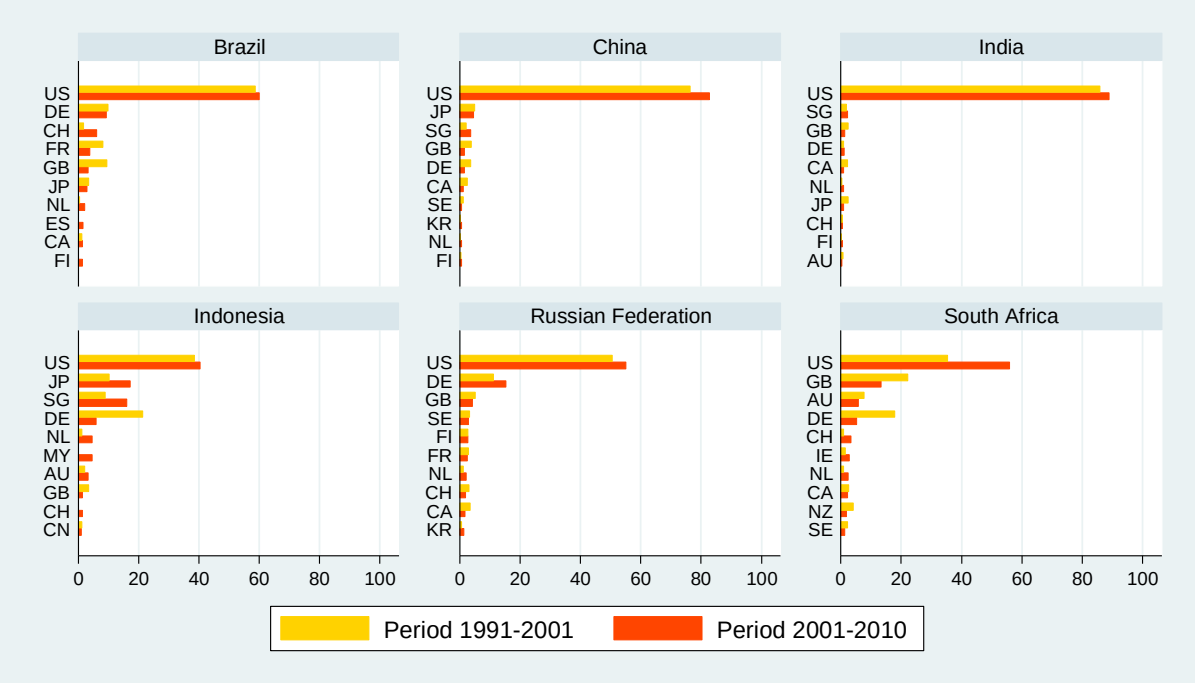


Figure 21.b:

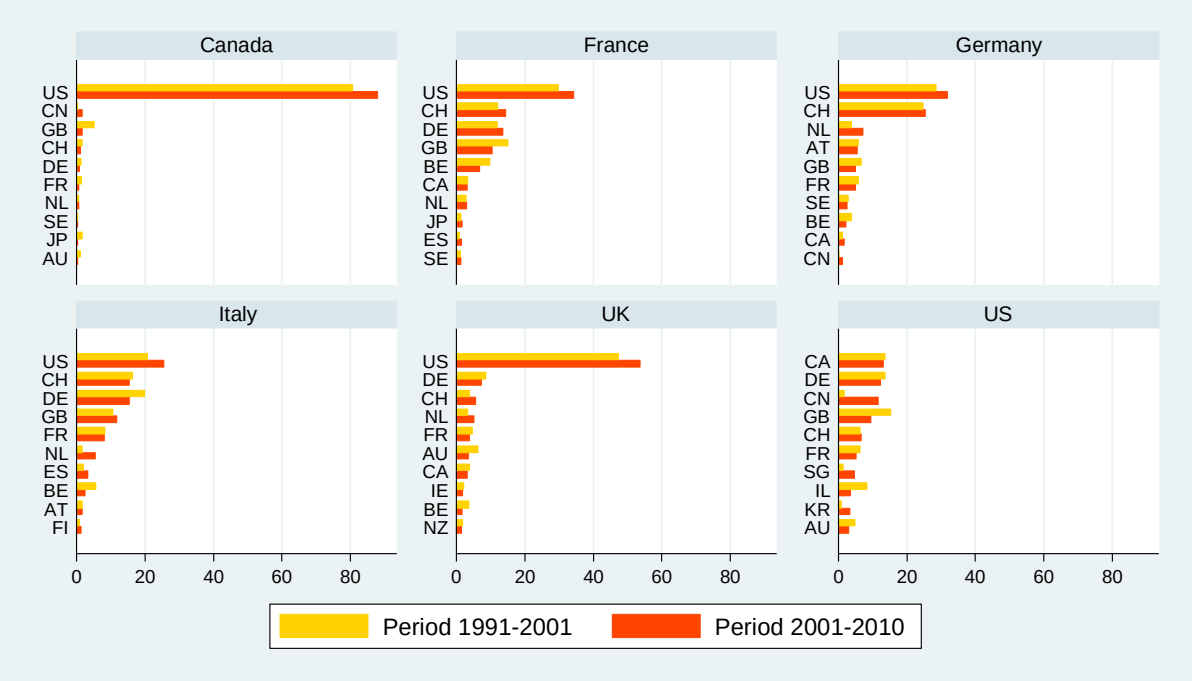
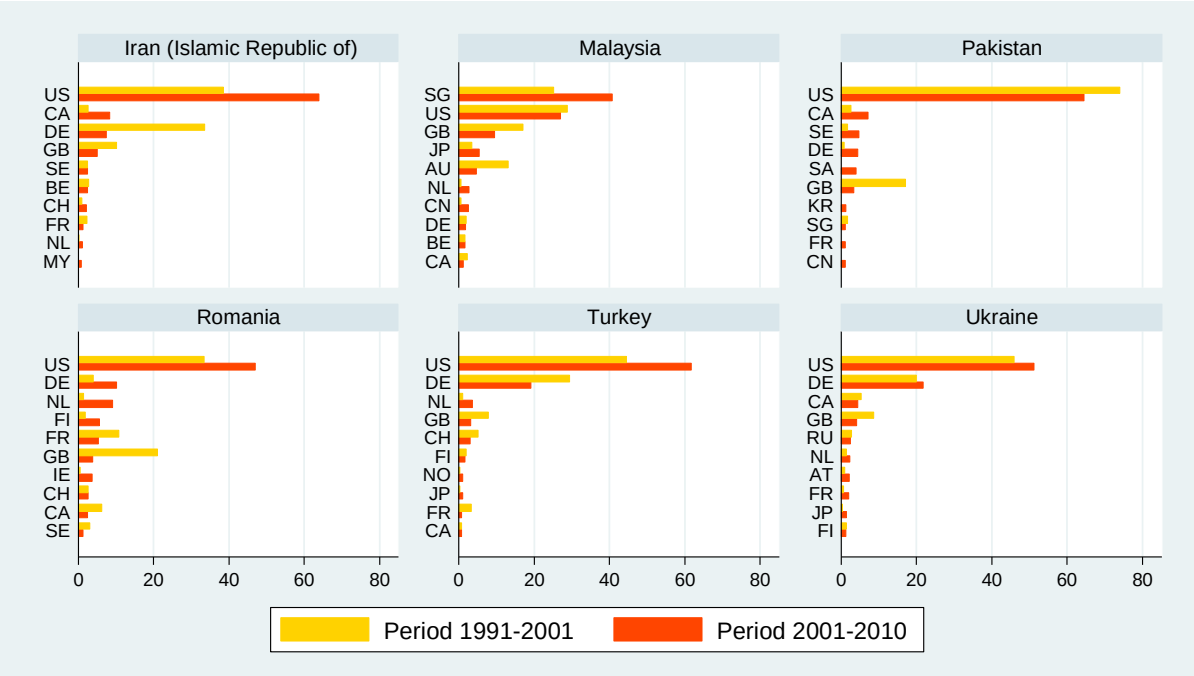


Figure 21.c:

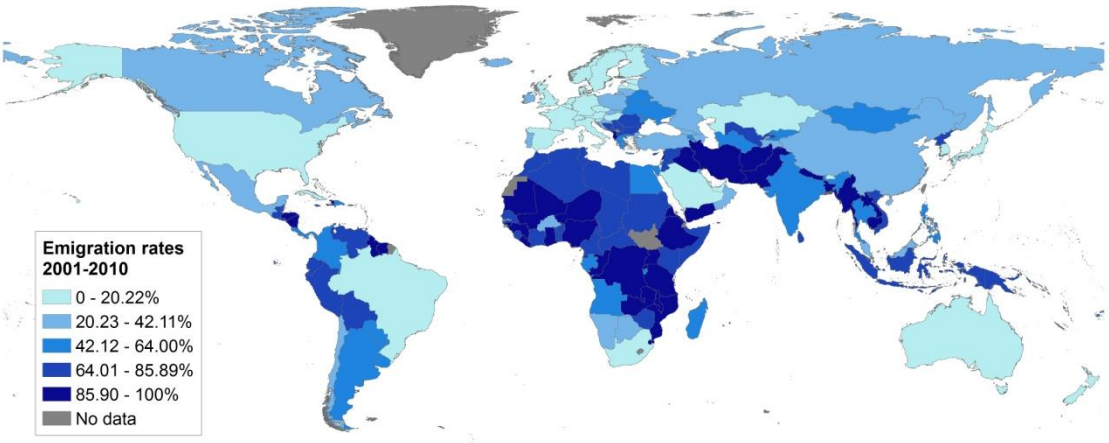


Note: Country codes in the vertical axes are AT: Austria, AU: Australia, BE: Belgium, CA: Canada, CH: Switzerland, CN: China, DE: Germany, ES: Spain, FI: Finland, FR: France, GB: United Kingdom, IE: Ireland, IL: Israel, JP: Japan, KR: Republic of Korea, MY: Malaysia, NL: the Netherlands, NO: Norway, NZ: New Zealand, RU: Russian Federation, SA: Saudi Arabia, SE: Sweden, SG: Singapore, and US: United States.

Figure 22 depicts emigration rates – or "brain drain" rates – in a map for the time window 2001-2010. The map confirms that low and middle income countries and especially African economies are the most severely affected by inventor "brain drain". However, some LAC and Asian economies seem to suffer from the brain drain of inventors, too. It is important to bear in mind at this point, and throughout the whole report, that some of these countries actually have very few resident inventors. This is because the number of inventors is a function of the number of PCT applications, which in turn depends on the level of

development. Given that the number of inventors enters the denominator of the brain drain rate, some of these countries present high emigration rates while there are, in fact, only few inventors abroad – especially as compared to, for instance, the college educated and doctors abroad.

Figure 22: Brain drain rates, 2001-2010[29]

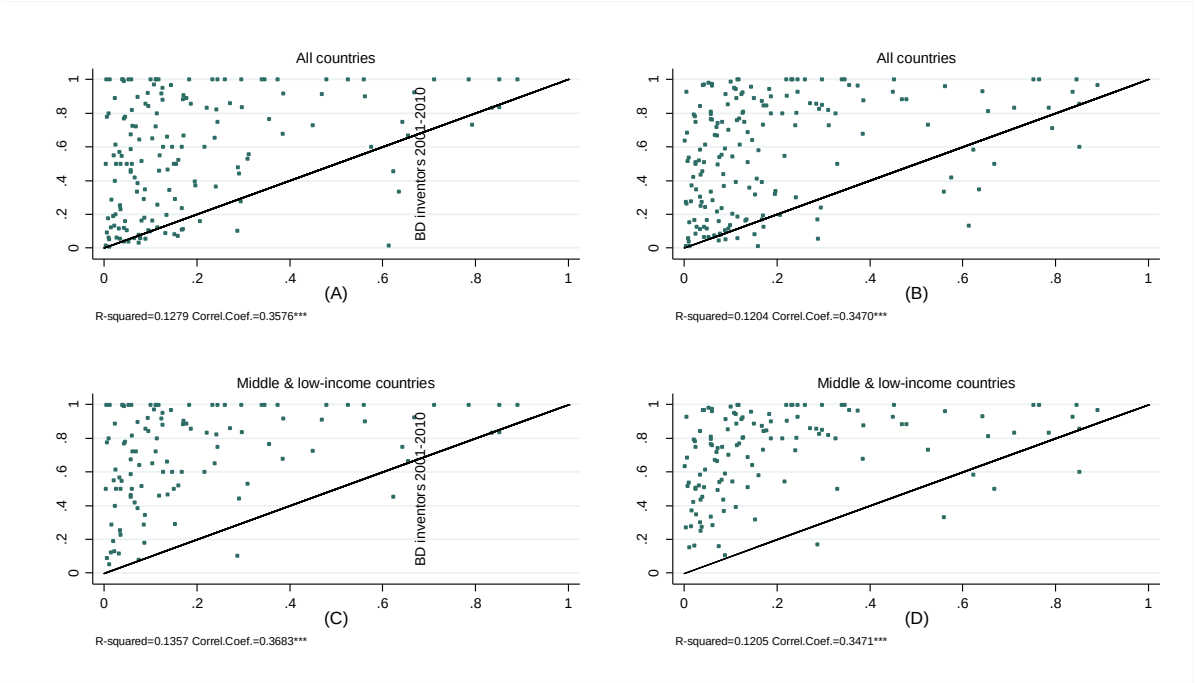


Given the country differences outlined above, it is worth exploring the correlation between the inventors' brain drain and the brain drain of tertiary educated persons based on 2000 census data. This is done in Figure 23, separately for the two periods under analysis and for all countries and for non-high income economies. Both scatterplots and estimated correlation coefficients show that, although the association between the two is not one-to-one, it is strongly positive and statistically significant. Again, low and middle income countries – panels (C) and (D) – are those further away from the main diagonal in the scatterplots which would indicate a perfect association between the two measures of brain drain. Therefore, for the majority of countries, but especially for low and middle income economies, inventor brain drain seems to be more severe than the tertiary educated brain drain.

One can also correlate inventor brain drain rates with measures of economic activity – mindful that statistical correlation does not imply causality one way or another. Figure 24 does so with constant 2005 GDP per capita in purchasing power parities (PPP), for the year 2005. It shows a clear negative association between the two variables – that is, the bigger the inventor brain drain, the lower the GDP per capita.

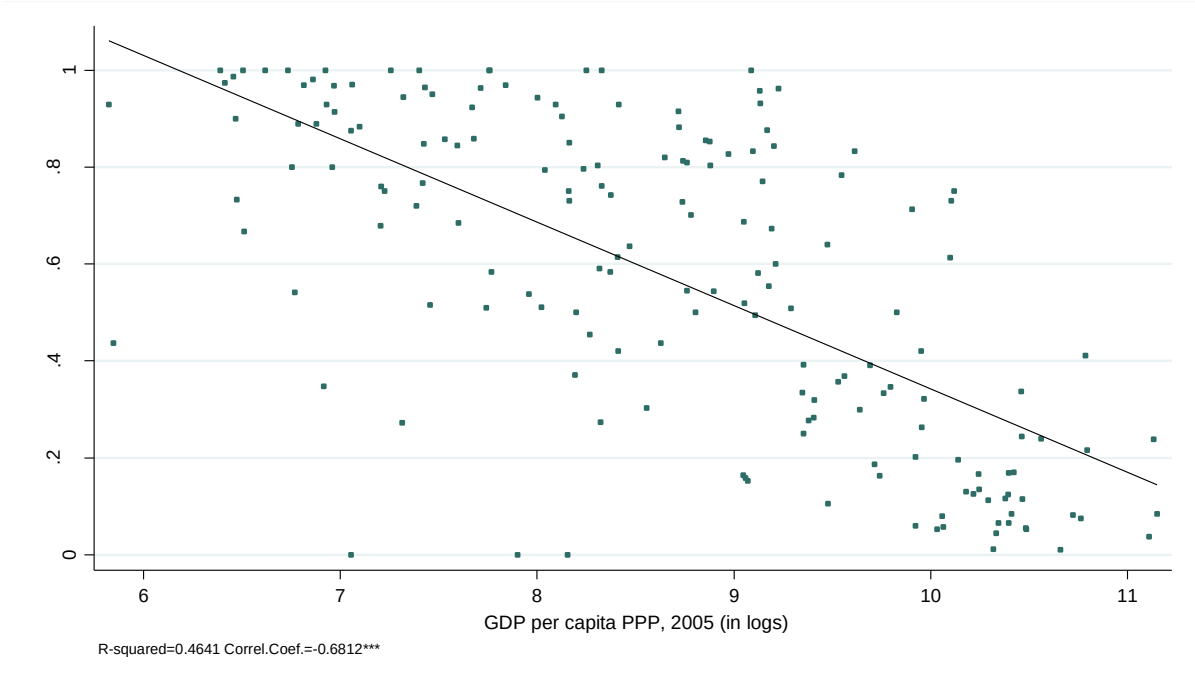
[29] Different methods to classify the values of variables (in our case, the emigration rate of inventors) into different classes in the map – and colors – exist. Two of the most common methods are classification in *quantiles* and classification into *equal intervals*. The former classifies data into a given number of categories with an equal number of observations in each category. This method however might classify two observations with very similar (or even equal) values into different classes. The *equal intervals* sets the value ranges in each category exactly equal in size. The problem with this method is that, when the data is skewed, there might be an extraordinary concentration of observations in one or few categories, making the visualization useless. A half-way solution between the two most common used methods, which we use in the present report, is the *Jenks natural breaks* classification method. This is an optimization method to decide the best arrangement of a variable into classes. In a nutshell, it consists on minimizing the variance within each class, while at the same time maximizing the variance between all the classes.

Figure 23: Inventor brain drain vs. college graduates brain drain



Note: Income groups according to the World Bank classification of 2012.

Figure 24: Inventor brain drain vs. per capita GDP



To better understand the implications of the brain drain of inventors for economic prosperity, it is also worth looking at the performance characteristics of those who left their country as compared to those who stayed. In particular, one can explore the average citations received by those inventors who stayed in their home countries and the average citations of the stock of emigrant inventors of that same countries, for a selection of high income and low and middle income economies (2012 World Bank classification). In particular, Table 16 focuses on the top-10 high income countries with the largest inventor emigrant stocks during the 2001-2010 period, and the top-10 low and middle income economies with the largest emigrant stocks in that same period. It systemically shows more citations received, on

average, by the emigrant inventors as compared to non-migrating co-nationals (Table 16). The differences are statistically significant, except for the case of the US and Romania (see the last column of Table 16).

Table 16: Citations received by nationals-residents vs. diaspora

	Average citations by nationals in home country	Average citations received by emigrants	Significance difference
Top-10 largest diaspora. High income countries			
Germany	1.03	1.53	t-statistic=35.32*** p-value=0.000
UK	1.79	1.97	t-statistic=8.40*** p-value=0.000
Canada	1.37	1.66	t-statistic=11.73*** p-value=0.000
France	0.93	1.56	t-statistic=36.42*** p-value=0.000
US	1.31	1.36	t-statistic=1.62 p-value= 0.106
Italy	1.17	1.32	t-statistic=6.06*** p-value=0.000
Netherlands	1.39	1.61	t-statistic=7.45*** p-value=0.000
R. of Korea	0.64	1.22	t-statistic=29.83*** p-value=0.000
Japan	0.88	1.35	t-statistic=18.74*** p-value=0.000
Australia	1.24	1.65	t-statistic=12.19*** p-value=0.000
Top-10 largest diaspora. Middle and low income countries			
China	0.20	1.85	t-statistic=126.95*** p-value=0.000
India	1.16	1.34	t-statistic=9.51*** p-value=0.000
Russia	0.47	1.40	t-statistic=38.97*** p-value=0.000
Turkey	0.59	1.04	t-statistic=12.02*** p-value=0.000
Malaysia	0.31	1.03	t-statistic=17.46*** p-value=0.000
Romania	0.87	0.92	t-statistic=0.73 p-value=0.466
Iran	0.58	1.16	t-statistic=2.06** p-value= 0.0394
Ukraine	0.28	1.06	t-statistic=17.20*** p-value=0.000
Brazil	0.59	0.98	t-statistic=9.23*** p-value=0.000
Mexico	0.44	1.52	t-statistic=16.42*** p-value=0.000

Note: Income groups according to the World Bank classification of 2012. ***, **, and * indicates significance at 1, 5, and 10 percent levels respectively.

At first, Table 16 seems to suggest that countries lose their ‘best and brightest’ individuals with inventor migration, with all the implications this phenomenon may bring about – either negative, such as depletion of human capital, or positive, such as the benefits of having

high-skilled intellectual diasporas abroad.[30] The US diaspora abroad is not significantly more productive than its native counterparts that stay in their home country. This may suggest that the effect found is not the result of emigrants being more productive than stayers but simply the US being a more productive country – measured by citations received. Recent research claims that frontier economies provide talented migrants the best environment for their work (Kahn and MacGarvie, forthcoming), and that scientists that must relocate outside of the United States due to "exogenous" reasons perform worse in terms of publications and citations in a place with low income per capita (op. cit.).

As a summary, Table 17 lists the top-10 countries, in terms of stocks of immigrants, stocks of emigrants and brain drain rates. As expected, the immigrant list is populated mostly with high income economies, probably reflecting the attractive employment, education, research, and entrepreneurship opportunities offered by these economies. Interestingly, most high income countries also show sizeable emigrant stocks abroad, although China and India emerge as the top two inventor sending countries in the 2001-2010 period. When looking at relative emigration rates – which take into account the size of local inventor endowments – low and middle income countries dominate the top-10 list, especially small and African economies. For completeness, Appendix 3 lists all the countries/territories of our sample alongside their stocks of inventor immigrants, their stocks of inventor emigrants, and their inventor emigration rate, for the two time periods under consideration.

Table 17: Immigrants, emigrants and emigration rates, 1991-2000 and 2001-2010

Country/ territory	Immig.	Nationals	Country/ territory	Emig.	Residents	Country/ territory	Emig. rates
			Period 1991-2000				
US	31,358	163,725	UK	8,930	73,166	Iran	96.79
Germany	6,887	176,311	China	8,206	6,775	Pakistan	95.08
UK	5,248	67,918	Germany	7,216	183,198	Algeria	91.97
Switzerland	4,544	11,428	India	5,193	1,552	Lebanon	91.76
France	2,909	53,934	France	3,350	56,843	Ghana	91.23
Australia	2,051	16,791	Canada	3,286	17,410	Cameroon	90.57
Canada	1,943	15,467	US	3,205	195,083	Jordan	89.74
Belgium	1,760	8,661	Italy	2,068	18,514	Morocco	88.39
Japan	1,376	156,488	Austria	1,993	8,179	Tunisia	88.14
Sweden	1,340	27,700	Netherlands	1,986	16,991	Viet Nam	85.92
			Period 2001-2010				
US	194,609	875,962	China	53,610	141,902	Nepal	98.11
Germany	25,341	432,136	India	40,097	38,486	Bangladesh	96.96
Switzerland	20,416	32,737	Germany	32,158	457,477	Mauritius	96.15
UK	15,758	119,824	UK	27,746	135,582	Iran	95.71
Netherlands	9,665	60,513	Canada	21,315	65,808	Nigeria	95.04
France	9,540	141,413	France	19,123	150,953	Iraq	94.35
Canada	7,257	58,551	US	11,131	1,070,571	Pakistan	92.29
Singapore	6,720	6,311	Italy	9,820	62,973	Albania	91.45
Japan	6,715	578,101	Netherlands	9,132	70,178	Tanzania	91.36
Belgium	5,042	22,122	R. of Korea	9,127	164,078	Ghana	88.37

Note: The last column shows the emigration rates only if the country has at least 5 resident inventors (both nationals and immigrants).

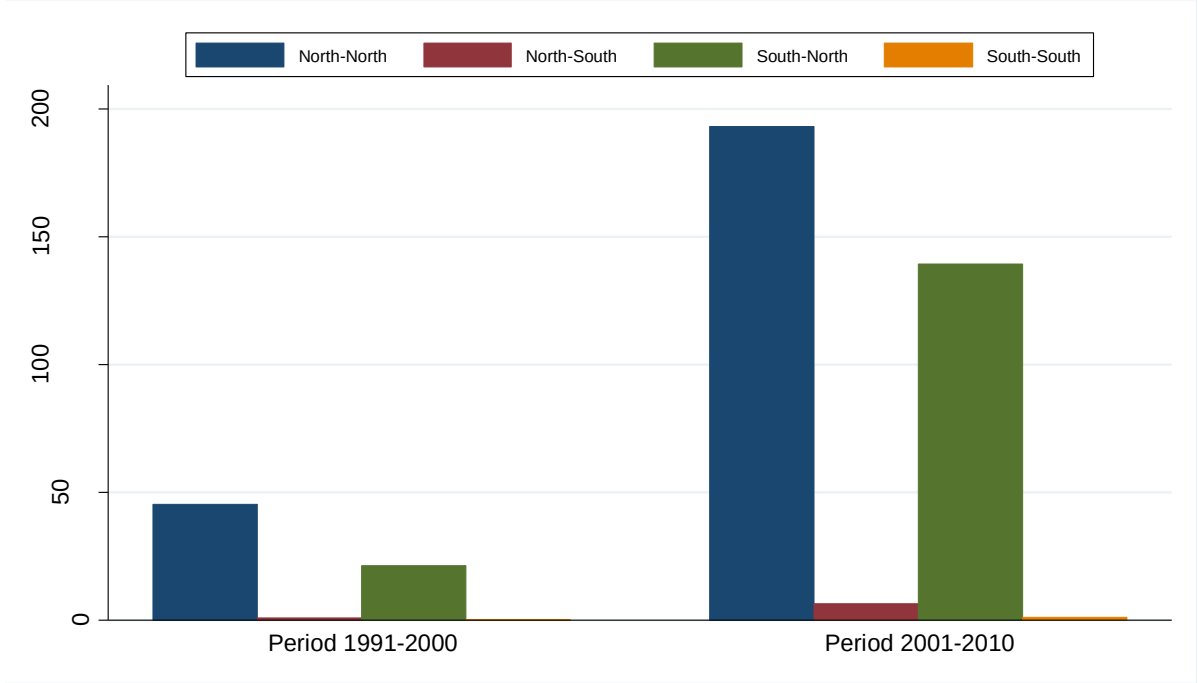
[30] Admittedly, the number of citations per patent is largely dependent on the patent's technology field. If migrant inventors concentrate in highly-cited sectors (see subsection 5.4), one may simply capture a composition effect and not a productivity effect. However, a citation analysis disaggregating nationals and emigrants by technology fields is beyond the scope of this report.

5.3. Migration corridors

The bilateral nature of our data makes it possible to identify the main inventor migration corridors. In particular, Figure 25 depicts the absolute number of inventor migration in four pre-defined aggregated corridors, for the two time periods under analysis: the North-North corridor (between high income economies), the North-South corridor (from high income to low and middle income countries), the South-North corridor, and the South-South corridor. It shows that the absolute number of migrant inventors has increased considerably between the two periods in all corridors. The North-North corridor is the most important one in both periods, although the South-North corridor is nearly as large.

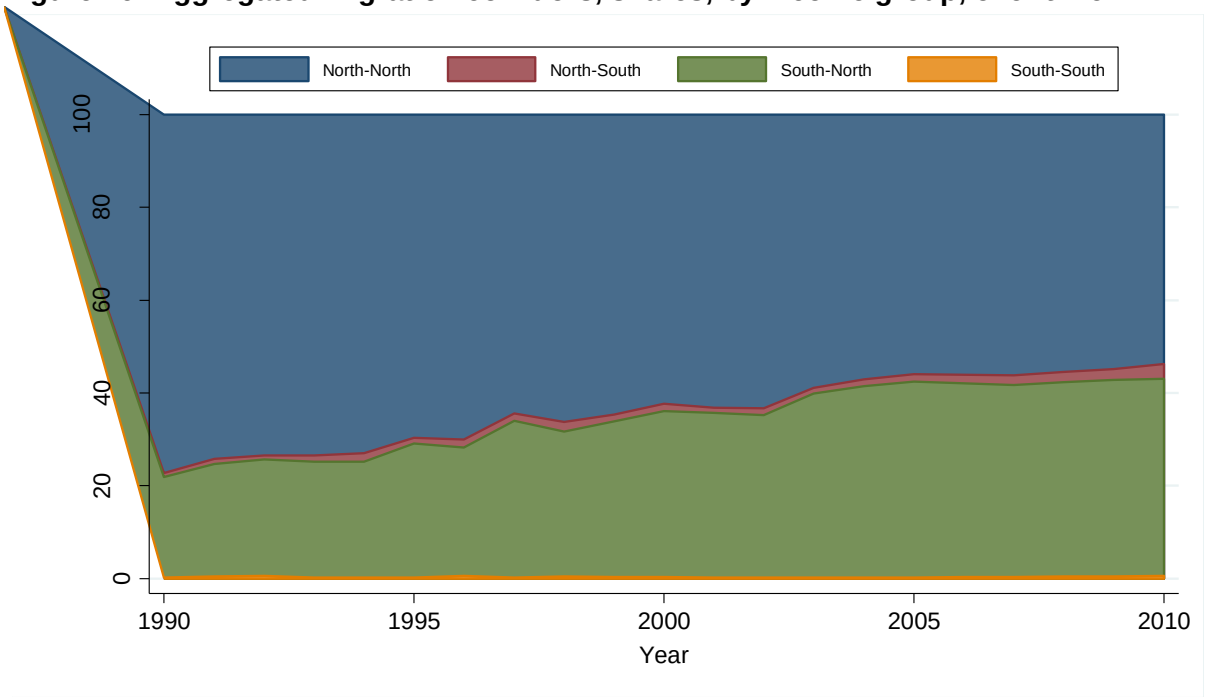
Interestingly, when plotting the share of inventors present in each corridor over time, as a percentage of all migrant inventors, it is possible to see how the South-North corridor has gained prominence over the years (Figure 26), although the North-North corridor still hosts most migrants.

Figure 25: Aggregated migration corridors, by income group



Note: Income groups according to the World Bank classification of 2012.

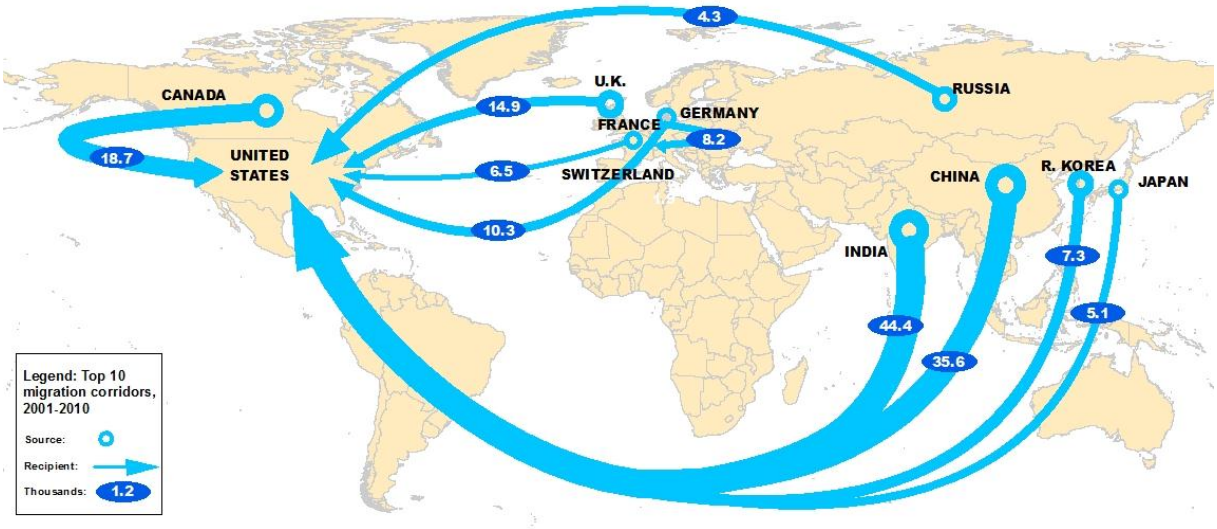
Figure 26: Aggregated migration corridors, shares, by income group, over time



Note: Income groups according to the World Bank classification of 2012.

Figure 27 plots the top-10 most populated corridors in a map, for the 2001-2010 period. As expected, the US emerges as the most frequent destination country. Most origin countries are other high income countries, although the top two corridors – China-US and India-US, have middle income country origins.

Figure 27: Top-10 migration corridors, 2001-2010



Tables 18 and 19 list the 30 most important corridors for the 1991-2000 and 2001-2010 periods, respectively – both with (left hand side) and without (right hand side) the US as receiving country. These 30 corridors account for only 0.08 percent of all country/territory pairs in the dataset. However, they represent 51.76 percent and 58.70 percent of overall migration counts for the two time periods, respectively. In other words, inventor migration is a phenomenon that is highly concentrated among a relatively small number of country pairs. In line with Figures 27, the US appears most frequently in these lists as a destination country, while other high income economies are usually the source country – with the

exceptions mentioned above.[31] When removing the US from the analysis, intra-European flows of inventors dominate the top corridors, with interesting exceptions – such as The UK-Australia corridor (1991-2000) or the China-Japan and China-Singapore corridors (2001-2010).

Table 18: Largest inventor migration corridors, 1991-2000

Largest inventor migration corridors			Largest inventor migration corridors without US		
Origin	Destination	Counts	Origin	Destination	Counts
China	US	6,279	Germany	Switzerland	1,786
India	US	4,470	Austria	Germany	1,362
UK	US	4,249	UK	Germany	780
Canada	US	2,652	UK	Australia	576
Germany	US	2,055	France	UK	513
Germany	Switzerland	1,786	US	UK	490
Austria	Germany	1,362	Germany	UK	476
France	US	1,003	US	Canada	437
Japan	US	857	US	Germany	436
Russia	US	842	UK	France	435
UK	Germany	780	Germany	France	432
UK	Australia	576	Germany	Austria	429
Australia	US	569	Ireland	UK	419
R. of Korea	US	546	Italy	Germany	416
Israel	US	522	France	Switzerland	406
France	UK	513	France	Germany	403
US	UK	490	China	Japan	402
Germany	UK	476	Netherlands	Germany	384
US	Canada	437	Belgium	France	373
US	Germany	436	UK	Switzerland	355
UK	France	435	UK	Canada	352
Germany	France	432	Italy	Switzerland	340
Switzerland	US	431	France	Belgium	330
Italy	US	430	China	UK	328
Germany	Austria	429	UK	Belgium	328
Sweden	US	426	China	Germany	311
Netherlands	US	420	UK	Netherlands	304
Ireland	UK	419	Germany	Netherlands	296
Italy	Germany	416	Austria	Switzerland	294
France	Switzerland	406	Germany	Belgium	290

[31] This also holds for the general population of migrants (Docquier et al. 2013).

Table 19: Largest inventor migration corridors, 2001-2010

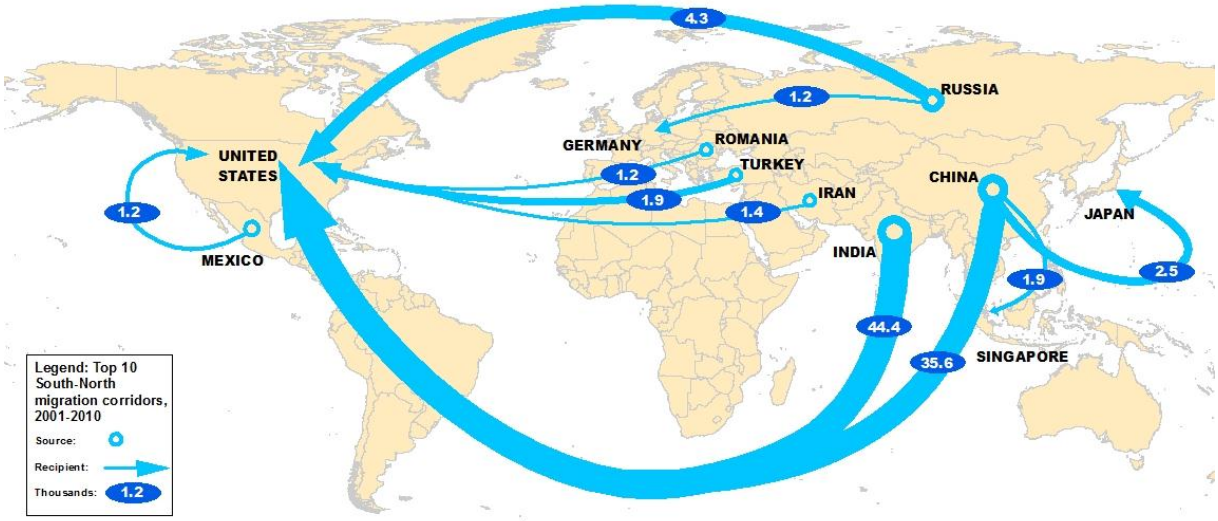
Largest inventor migration corridors			Largest inventor migration corridors without US		
Origin	Destination	Counts	Origin	Destination	Counts
China	US	44,452	Germany	Switzerland	8,198
India	US	35,621	France	Switzerland	2,747
Canada	US	18,734	Austria	Germany	2,672
UK	US	14,893	France	Germany	2,607
Germany	US	10,297	China	Japan	2,510
Germany	Switzerland	8,198	Germany	Netherlands	2,285
R. of Korea	US	7,267	Netherlands	Germany	2,138
France	US	6,543	France	UK	2,044
Japan	US	5,045	UK	Germany	2,043
Russia	US	4,339	China	Singapore	1,923
Australia	US	3,241	Germany	Austria	1,829
Israel	US	2,966	Germany	UK	1,612
France	Switzerland	2,747	Germany	France	1,609
Netherlands	US	2,698	UK	Switzerland	1,555
Austria	Germany	2,672	Italy	Switzerland	1,536
France	Germany	2,607	Italy	Germany	1,529
China	Japan	2,510	UK	Netherlands	1,456
Italy	US	2,501	US	Canada	1,454
Germany	Netherlands	2,285	US	Germany	1,384
Netherlands	Germany	2,138	France	Belgium	1,347
France	UK	2,044	Spain	Germany	1,298
UK	Germany	2,043	US	China	1,295
China	Singapore	1,923	Russia	Germany	1,207
Turkey	US	1,922	Italy	UK	1,155
Germany	Austria	1,829	UK	France	1,121
Germany	UK	1,612	Malaysia	Singapore	1,090
Germany	France	1,609	R. of Korea	Japan	1,080
Spain	US	1,559	US	UK	1,058
UK	Switzerland	1,555	UK	Australia	977
Italy	Switzerland	1,536	China	UK	920

Figure 28 looks at the top-10 migration corridors for which the sending country is not a high income economy – according to the 2012 World Bank classification, for the period 2001-2010. It graphically illustrates the importance of the US as a destination country, as discussed in subsection 5.1. It also illustrates the importance of China and India as sending countries, with Russia, Turkey, Iran, Romania, and Mexico emerging as other top sending countries.

Appendix 4 shows the top-30 most populated corridors originating from a low or middle income economy, with and without including the US among the destination countries. Again, the US emerges by far as the most frequently listed destination country in both periods. Germany is the only continental European country appearing in this list. Interestingly, Singapore – despite its relatively small size – appears several times as a destination country in these lists, with China, India and Malaysia as the most important inventor origins.[32]

[32] For completeness, Table A6 in Appendix 4 shows the most populated corridors from high income to non-high income countries (North-South migration), for the two time periods. For the 2001-2010 period, China overwhelmingly dominates the majority of North-South corridors, with few exceptions – like South Africa, India, and Malaysia. Table A7, in turn, lists the top-30 South-South corridors – those only involving low and middle income economies at both ends. As in Figures 25 and 26, these corridors represent a tiny share of all

Figure 28: Top-10 South-North migration corridors, 2001-2010



Note: Income groups according to the World Bank classification of 2012.

Table 20 lists all the bilateral country pairs where the ratio of the flow from origin to destination over the reverse flow is between 0.5 and 2; it orders pairs by the sum of the two flows, for both periods under analysis. The corridors listed can be considered as having fairly balanced inventor migration flows. The resulting flows appear to reflect in large part the establishment of a single labor market in Europe.[33] Aside from EU corridors, other interesting corridors that feature in the top-30 list include US-Israel (1991-2000), Switzerland-US, China-Germany, and Singapore-US. Interestingly, China features in several of these corridors in the second period, witnessing the rise of the country not only as a source of inventors for other countries, but also as a host for inventors from many other economies – especially other Asian and European economies.

internationally mobile inventors. Nonetheless, it is interesting to observe that the pattern of South-South mobility of inventors seems to be dominated by regional (intra-continent) flows.

[33] Within Europe, some of the largest bilateral flows are among countries sharing the same or similar languages or those which are contiguous.

Table 20: Largest bilateral migration corridors, 1991-2000 and 2001-2010

Largest dual direction migration corridors, 1991-2000				Largest dual direction migration corridors, 2001-2010			
Origin (A)	Destin. (B)	A → B	B → A	Origin (A)	Destin. (B)	A → B	B → A
UK	Germany	780	476	Austria	Germany	2,672	1,829
France	UK	513	435	Germany	Netherlands	2,285	2,138
Germany	France	432	403	France	Germany	2,607	1,609
Israel	US	522	273	UK	Germany	2,043	1,612
Belgium	France	373	330	France	UK	2,044	1,121
Netherlands	Germany	384	296	Switzerland	US	1,348	734
Ireland	UK	419	210	UK	Australia	977	609
UK	Netherlands	304	205	Netherlands	Belgium	890	535
Germany	Belgium	290	147	Ireland	UK	808	568
Italy	UK	225	146	China	Germany	892	468
UK	N. Zealand	180	98	Singapore	US	775	518
Italy	France	177	100	Netherlands	France	644	580
UK	Sweden	164	84	Germany	Belgium	694	406
Denmark	UK	120	102	China	Canada	652	387
France	Netherlands	98	86	Japan	Germany	502	280
Japan	Germany	83	81	UK	N. Zealand	418	342
Norway	Sweden	75	56	Spain	France	420	304
Singapore	US	65	52	Germany	Denmark	402	292
Japan	UK	73	39	Sweden	Denmark	377	250
Ireland	Germany	54	53	UK	Sweden	363	251
Netherlands	Sweden	67	39	UK	Denmark	367	214
Sweden	France	58	40	Australia	China	327	246
Finland	UK	50	47	Finland	Sweden	317	182
Germany	S. Africa	54	42	Germany	Finland	264	188
Canada	Japan	61	33	Japan	UK	255	175
Australia	Canada	54	39	France	China	211	183
UK	Singapore	54	39	Sweden	Norway	196	179
Germany	Finland	48	42	UK	Norway	238	119
Israel	UK	57	31	S. Africa	UK	172	128
Canada	Switzerland	54	31	Ireland	Germany	149	141

5.4. Differences across technologies

This section explores differences in inventor migration patterns across technology domains. This is partly motivated by previous research that has found that immigrants' contribution to their host countries productivity is mainly driven by those specializing in specific sectors that happen to be more productive – the so-called composition effect (Hunt and Gauthier-Loiselle 2010). In light of these claims, this section provides some initial insights into differences of inventor mobility patterns across different technology sectors. It follows Schmoch's (2008) classification of IPC codes into 35 technology fields, and groups them into 5 broad sectors – namely, electrical engineering, instruments, chemistry, mechanical engineering, and others (see Appendix 5).[34]

[34] Note that some patents, and therefore some inventors, might be classified in more than one technology. Adding up the absolute number of inventors across the 5 broad sectors thus results in a larger number of inventors than those considered in the previous sections.

Figure 29 looks at the migration rate of inventors across sectors, over time.[35] Electrical engineering and chemistry emerge as the most important technology fields. The case of electrical engineering – audio-visual technology, telecommunications, digital communications, computer technology, IT methods, semiconductors, etc. – is especially remarkable, showing a sudden jump in its migration rate around 2003-2004.[36]

Figure 29: Migration rates over time, by technologies

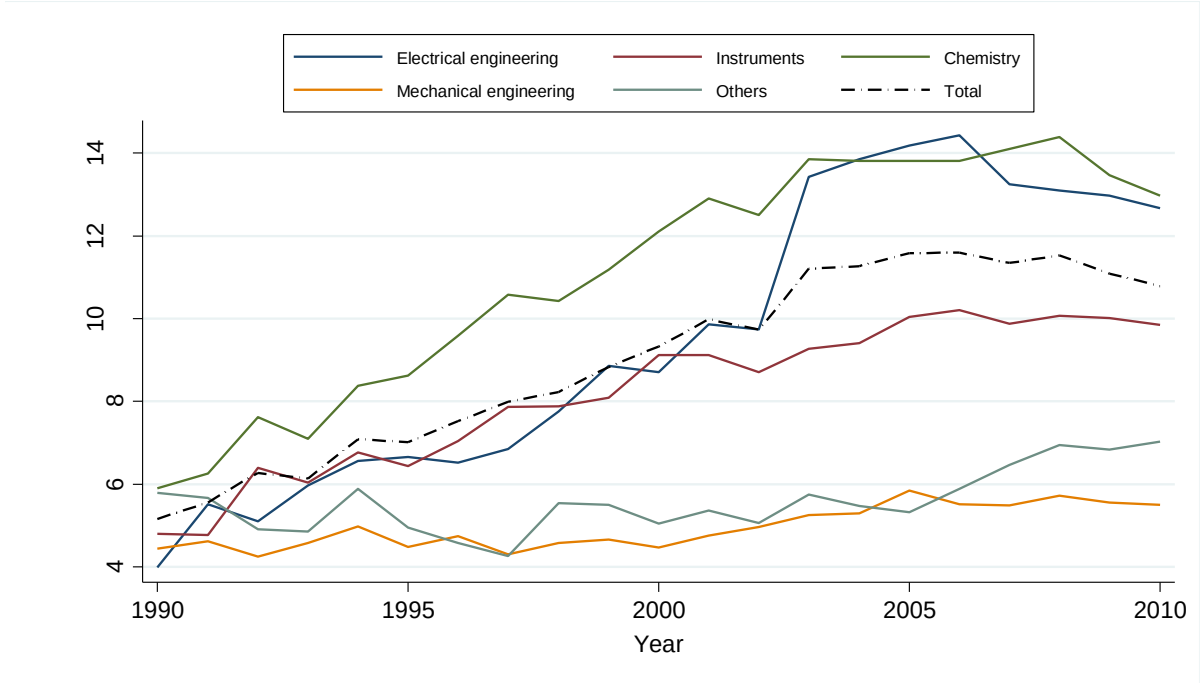
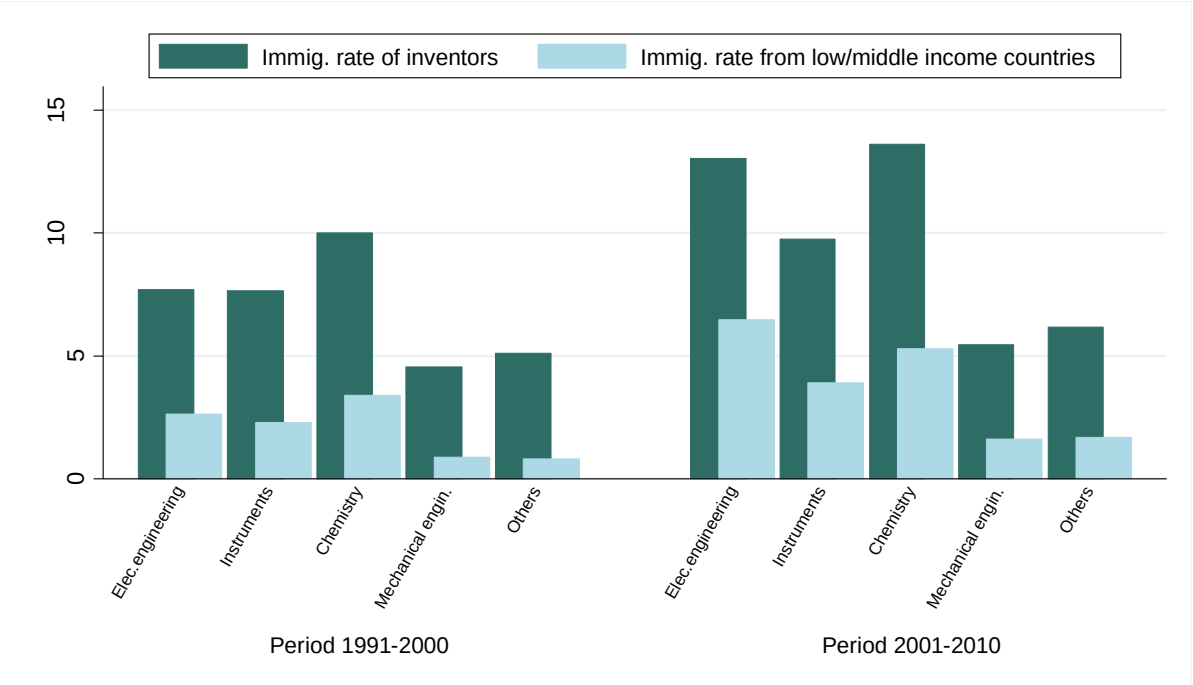


Figure 30 confirms how the migration rate of inventors has increased over time, especially in electrical engineering and chemistry that stand out in terms of mobility. Interestingly, when focusing only on migrant inventors from low and middle income economies, electrical engineering clearly stands out over the others – even over chemistry, which leads the ranking of total migration rates. The large numbers of Chinese and Indian inventors in sectors such as telecommunications, computer technology, IT methods and semiconductors may largely explain these figures. Indeed, Figure 31 depicts the distribution of migrant inventors by origin country for each technology field. Indian and Chinese inventors account for large shares in electrical engineering, alongside the remaining Asian countries. Mechanical engineering emerges as the most important technology field for European – and especially German – inventors.

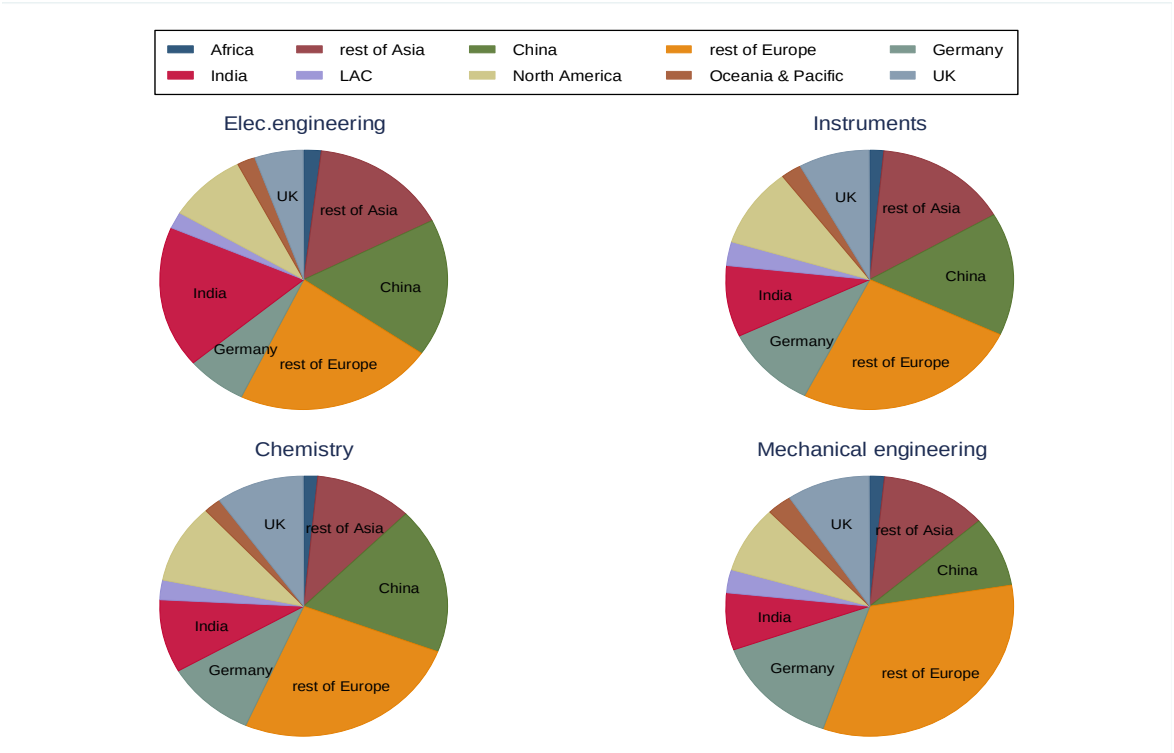
[35] Note that the total migration rate (dashed-dotted line) is slightly larger than the world migration rate estimated in Figure 2. This small difference suggests that migrant inventors specialize in patents that are broader in technological terms – and therefore are double-counted more disproportionately than natives.
[36] The abrupt shift around 2003-2004 may reflect the change of PCT rules in 2004 that provided that all PCT applications automatically include all PCT member states as designated states, which increased considerably the nationality/residence information coverage for this country – see Appendix 1.

Figure 30: Migration rates, by technology, 1991-2000 and 2001-2010



Note: Income groups according to the World Bank classification of 2012.

Figure 31: Total number of migrant inventors across technologies, 2001-2010.



Appendix 6 provides the migration rates of inventors across a finer classification of technologies – 35 technologies – both total and for inventors from non-high income economies. Migration rates range between 4 percent and more than 17 percent. Sectors such as computer technology, organic fine chemistry, analysis of biomaterials, pharmaceuticals, biotechnology, digital communication, and nano-technology attract a large share of immigrants – above 13 percent; at the other end of the spectrum, mechanical

elements, transport, and machine tools see inventor immigration rates of only around 4 percent.

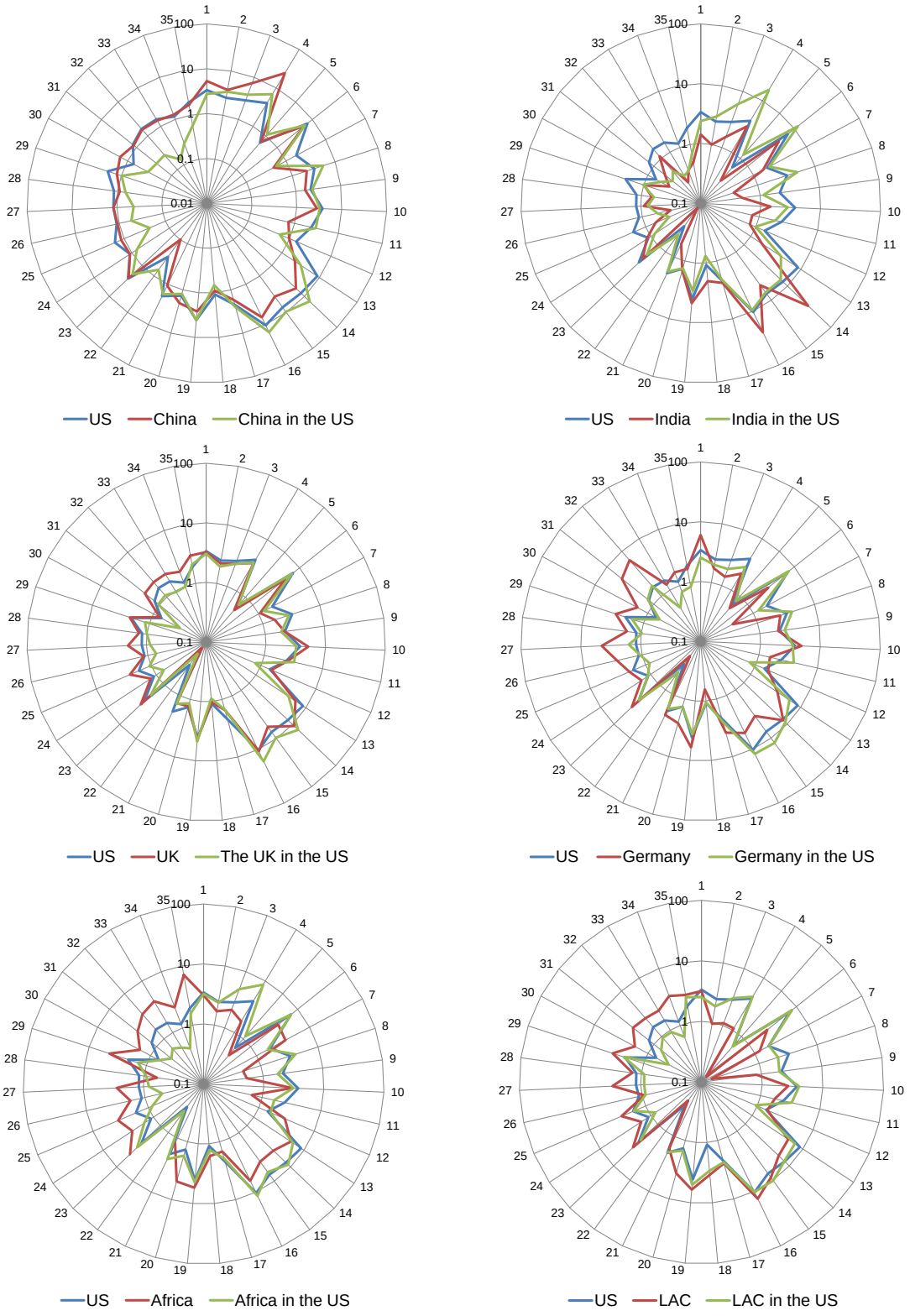
For completeness, Tables A10 to A13 in Appendix 7 show the top-30 most populated corridors, with and without the US, for the period 2001-2010, for four broad technology fields.

Figure 32 compares the technological specialization of resident inventors in the country hosting the largest immigrant stock – the US – with the technological specialization of immigrants from a selection of origin countries, as well as the specialization of their home countries. The idea behind this comparison is that the more similar the technological specialization between the host country and the migrants of a given origin country, and the larger the similarity between the latter and the specialization in their home countries, the larger may be the chances to observe international knowledge spillovers between the sending and the receiving countries. By contrast, if the technology specialization of these three groups is dissimilar, the opportunity for knowledge spillovers may be more limited.

Figure 32 looks at the 4 countries with the largest inventor emigrant stocks – namely, China, India, Germany and the UK– plus Africa and the LAC region, as a whole, and compares their technology specialization with the technology specialization of their emigrants in the US, and with the technology specialization of the US using all resident inventors in the US. For instance, the specialization patterns of the UK and the US are similar, as is the specialization pattern of UK inventor emigrants residing in the US. In such scenario, the potential of knowledge spillovers from the leading country, the US, to the UK are substantial. Chinese resident inventors seem to specialize in digital communications (4), and so do Chinese emigrants in the US, favoring the likelihood to observe spillovers in this field. By contrast, Chinese emigrants in the US are highly specialized in organic fine chemistry (14), biotechnology (15), and pharmaceuticals (16), as are US resident inventors. International US-China spillovers in these fields may therefore be less likely. In the case of India, the scope of spillovers in organic fine chemistry (14), biotechnology (15), and pharmaceuticals (16) seems comparatively stronger.

In the case of Africa, while the technology specialization of African emigrants in the US shows similarity to that of US residents, there is little similarity with African inventors in Africa, possibly limiting the scope for spillovers. Finally, the Latin American inventor diaspora in the US is more likely to channel knowledge back to their origin countries, as can be inferred from the similar pattern of specialization of Latin American inventors in the US and Latin American inventors at home.

Figure 32: Similarity between origin country, emigrant stocks, and host country (US), in percentage across technologies (in logarithmic scale)



Note: 1: Elec. machinery, energy; 2: Audio-visual tech.; 3: Telecommunications; 4: Digital communication; 5: Basic communication processes; 6: Computer tech.; 7: IT methods for management; 8: Semiconductors; 9: Optics; 10: Measurement; 11: Analysis of bio materials; 12: Control apparatus; 13: Medical technology; 14: Organic fine chemistry; 15: Biotech.; 16: Pharma.; 17: Macromolecular chemistry; 18: Food chemistry; 19: Basic materials chemistry; 20: Materials metallurgy; 21: Surface tech coating; 22: Micro-structure and nano-technology; 23: Chemical engineering; 24: Environmental technology; 25: Handling; 26: Machine tools; 27: Engines, pumps, turbines; 28: Textile and paper; 29: Other spec machines; 30: Thermal processes and apparatus; 31: Mechanical elements; 32: Transport; 33: Furniture, games; 34: Other consumer goods; 35: Civil engineering;

6. A CLOSER LOOK AT WORLD REGIONS

6.1. A closer look at Africa

This section and the following ones take a closer look at the specific case of African economies, countries from the LAC region, countries from the Middle East, South and East Asia and Oceania and the Pacific, and finally countries from Europe and Central Asia. Given the relatively small volume of patent filings in some of these countries, they often do not appear in the tables and figures presented in the previous sections. It is therefore insightful to explore the key patterns and trends on a region-by-region basis.

Figure 33 depicts the brain drain of inventors in African countries, for the two time periods under analysis. The maps show that an important number of African countries show brain drain rates above 64 percent. These large emigration rates of inventors resemble previous findings on the brain drain of African college graduates (Capuano and Marfouk 2013). Some countries – in particular, Mauritania, Ethiopia, Eritrea, Niger, Nigeria, Uganda or Mozambique – show emigration rates of inventors above 90 percent. Thus, inventors' brain drain appears to be disproportionally large in Africa and more pronounced than tertiary educated emigration rates. Conversely, countries such as South Africa, Botswana and Namibia seem to suffer less from the brain drain of inventors. As pointed out in subsection 5.2, one has to keep in mind that some of these countries actually have very few resident inventors at home. Given that the number of inventors enters the denominator of the brain drain rate, some of these countries present high emigration rates while there are, in fact, only few inventors abroad.

Figure 33: Brain drain in Africa, 1991-2000 and 2001-2010

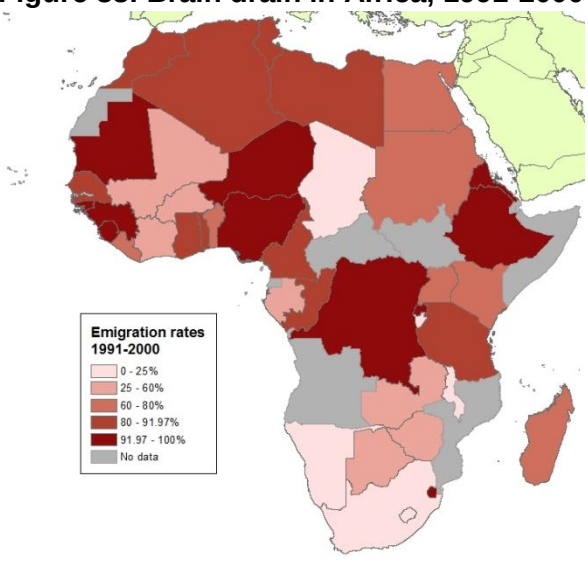


Figure 33a: Brain drain, 1991-2000

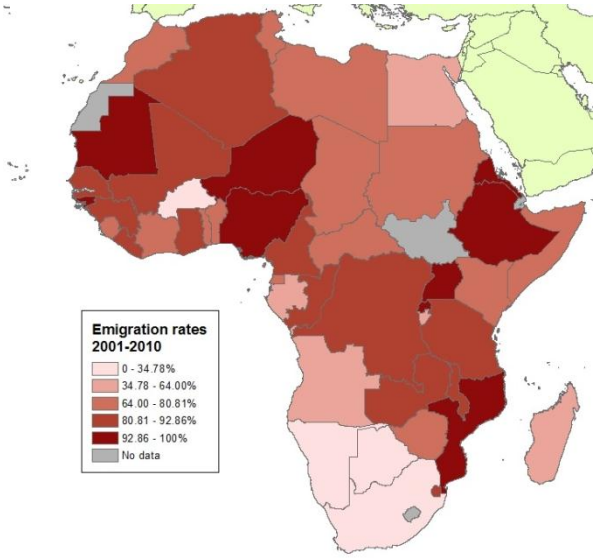


Figure 33b: Brain drain, 2001-2010

African inventor emigrants mainly reside in the US and in Europe (Figure 34). During 2001-2010, they represented 1.53 percent of all migrants going to the US and 2.15 percent of all migrants in Europe. Within Europe, France hosted up to 37 percent of all African inventors residing in the continent during 2001-2010, most likely reflecting a shared language and past colonial ties.

After the US and Europe, other countries such as Canada, Australia, Japan and Saudi Arabia also host African inventors. Interestingly, South Africa seems to be a regional hub in attracting talent from within the continent.

Figure 34: Where do African inventors go?

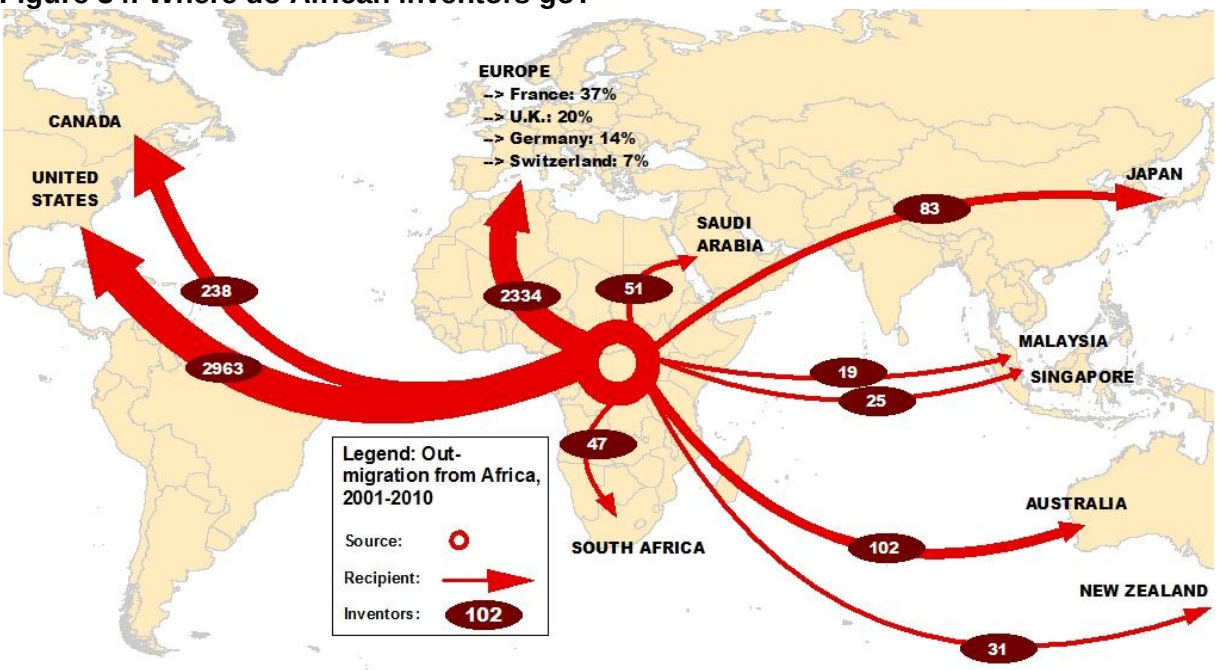
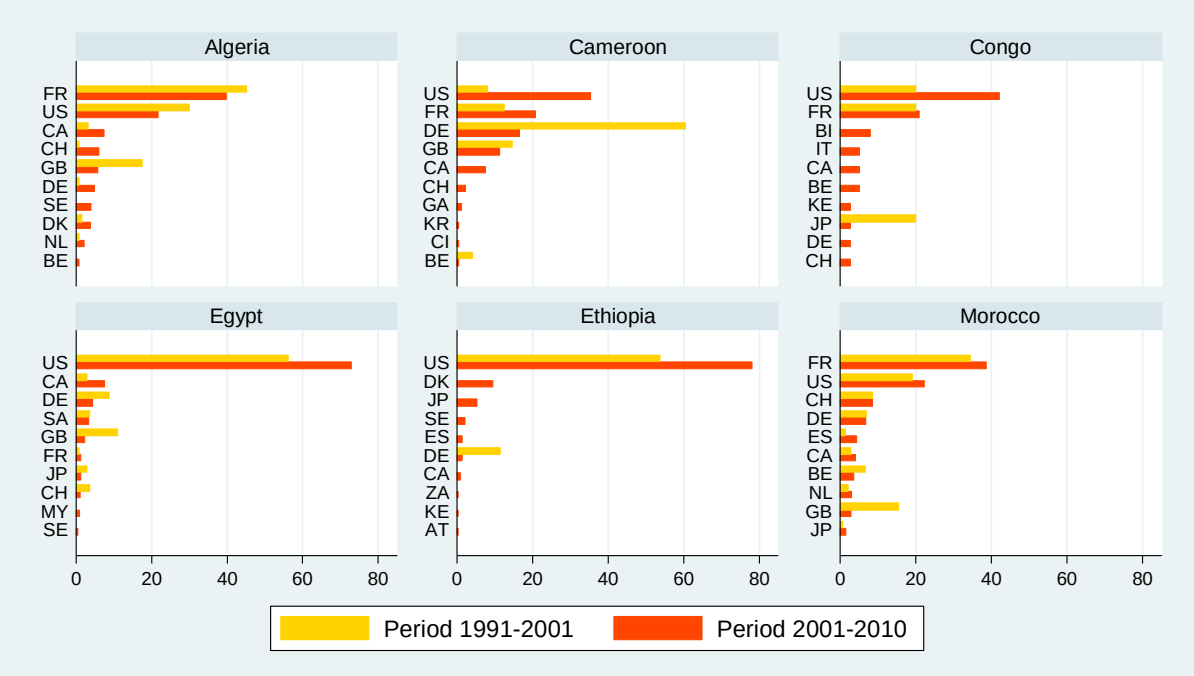


Figure 35 depicts, for a small selection of African economies, their most popular destinations as shares of all their inventors abroad. As we showed in subsection 5.2, the US clearly dominates this graph. However, because of geographical proximity, shared languages and historical linkages, European countries attract considerable talent from Africa as well. For instance, France ranks first or second in four out of the six countries depicted. Similarly, Denmark ranks second in attracting talent from Ethiopia.

Figure 35: Most popular destinations of African inventors, selected countries



Note: Country codes in the vertical axes are AT: Austria, AU: Australia, BE: Belgium, BI: Burundi, CA: Canada, CH: Switzerland, DE: Germany, DK: Denmark, ES: Spain, FI: Finland, FR: France, GA: Gabon, GB: United Kingdom, IT: Italy, JP: Japan, KE: Kenya, MY: Malaysia, NL: the Netherlands, SA: Saudi Arabia, SE: Sweden, US: United States, and ZA: South Africa.

In order to explore further the main destinations of African inventors, Table 21 shows the largest migration corridors originating from African countries. As advanced before, the US and France dominate the majority of the top-30 bilateral corridors originating from Africa, in both periods.

Table 21: Largest inventor migration corridors from African countries

Largest inventor migration corridors, 1991-2000			Largest inventor migration corridors 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
Tunisia	France	94	South Africa	US	719
South Africa	US	83	Egypt	US	667
Egypt	US	77	Tunisia	France	257
Nigeria	US	76	Nigeria	US	247
Morocco	France	68	Morocco	France	239
Algeria	France	57	Algeria	France	195
South Africa	UK	52	Ethiopia	US	178
South Africa	Germany	42	South Africa	UK	172
Algeria	US	38	Kenya	US	147
Morocco	US	38	Morocco	US	137
Ghana	US	38	Tunisia	US	124
Morocco	UK	31	Algeria	US	107
Cameroon	Germany	29	Ghana	US	105
Algeria	UK	22	South Africa	Australia	77
Nigeria	UK	21	Mauritius	US	76
Tunisia	Belgium	19	Egypt	Canada	69
South Africa	Australia	18	South Africa	Germany	67
Morocco	Switzerland	17	Cameroon	US	60
Kenya	US	16	Tunisia	Finland	58
Egypt	UK	15	Tunisia	Germany	57
Morocco	Germany	14	Tanzania	US	56
Ethiopia	US	14	Morocco	Switzerland	53
Tunisia	Germany	13	Uganda	US	52
Sudan	UK	13	Nigeria	UK	49
Morocco	Belgium	13	South Africa	Switzerland	42
Egypt	Germany	12	Morocco	Germany	41
Mauritius	US	12	Mauritius	UK	41
Libya	UK	12	Egypt	Germany	41
Mauritius	France	11	Zimbabwe	US	37
Togo	France	11	South Africa	Ireland	36

Although small in numbers, it is also worth looking at intra-African inventor migration. Table 22 lists the top-10 most populated corridors, for which both origin and destination countries are in Africa. As mentioned above, South Africa emerges as a regional hub in attracting talent from other African economies, hosting the continent's largest stock of immigrants.

At the same time, South Africa sees a large number of inventors migrating abroad, becoming the African country with the biggest emigrant stock (Table 23). Due to this duality, South Africa's inventor brain drain rate remains relatively low as compared to its continental neighbors.[37]

[37] South Africa's inventor brain drain remains even lower than for the brain drain of physicians and nurses, as reported in recent research (Bhargava et al. 2011).

Table 22: Largest inventor migration corridors among African countries

Largest inventor migration corridors, 1991-2000			Largest inventor migration corridors, 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
Zimbabwe	South Africa	5	Zimbabwe	South Africa	13
Tanzania	Kenya	2	Zambia	South Africa	5
Mauritius	South Africa	2	Nigeria	South Africa	5
Zimbabwe	Malawi	2	South Africa	Namibia	5
Nigeria	South Africa	1	Ghana	South Africa	4
Namibia	South Africa	1	D. R. Congo	South Africa	4
Congo	South Africa	1	Senegal	Cameroon	3
Ghana	Kenya	1	Kenya	South Africa	3
South Africa	Zambia	1	Malawi	South Africa	3
Zambia	South Africa	1	Congo	Burundi	3

Table 23: Immigrant and emigrant stocks, 2001-2010

Country/territory	Immigrant stocks	Country/territory	Emigrant stocks
South Africa	426	South Africa	1,281
Egypt	41	Egypt	913
Kenya	32	Morocco	617
Morocco	14	Tunisia	597
Tunisia	11	Algeria	488
Seychelles	9	Nigeria	345
Nigeria	8	Ethiopia	228
Namibia	8	Kenya	182
Algeria	6	Cameroon	169
Ghana	5	Ghana	152

Finally, Table 24 compares the average citations received by national inventors residing in their home country to those received by national inventors residing abroad, for the top-10 countries in terms of inventor emigrant stock size. As we found before, emigrants seem to be more productive than their co-nationals at home, as measured by the average number of citations received within 5 years after a patent's application. However, contrary to what subsection 5.2 reported, the difference is not statistically significant in 4 out of 10 case. However, the sample of national-resident inventors in some of the countries included is considerably smaller than in subsection 5.2, thus reducing statistical inference.

Table 24: Citations received by nationals-residents vs. diaspora

	Average citation received by nationals in home country	Average citations received by emigrants	Significance difference
South Africa	0.92	1.01	t-statistic=1.53 p-value=0.126
Egypt	0.33	1.22	t-statistic=8.03*** p-value=0.000
Morocco	0.32	1.22	t-statistic=5.72*** p-value=0.000
Tunisia	0.49	1.02	t-statistic=2.74*** p-value=0.001
Algeria	0.31	1.15	t-statistic=2.90*** p-value=0.001
Nigeria	0.58	1.61	t-statistic=1.05 p-value= 0.2924
Ethiopia	0.00	2.36	t-statistic=0.79 p-value= 0.4283
Kenya	0.34	1.47	t-statistic=2.87*** p-value=0.001
Cameroon	0.06	0.88	t-statistic=2.32** p-value=0.021
Ghana	0.61	1.48	t-statistic=1.55 p-value= 0.122

Note: ***, **, and * indicates significance at 1, 5, and 10 percent levels respectively.

6.2. A closer look at Latin America and the Caribbean

This section provides similar analysis for countries in the LAC region.

Figure 36 depicts the brain drain of inventors, showing that smaller states seem to suffer the most severe brain drain. Meanwhile, larger countries like Brazil, Colombia, Mexico, Chile and Argentina are less affected.

Figure 36: Brain drain in the LAC region, 1991-2000 and 2001-2010

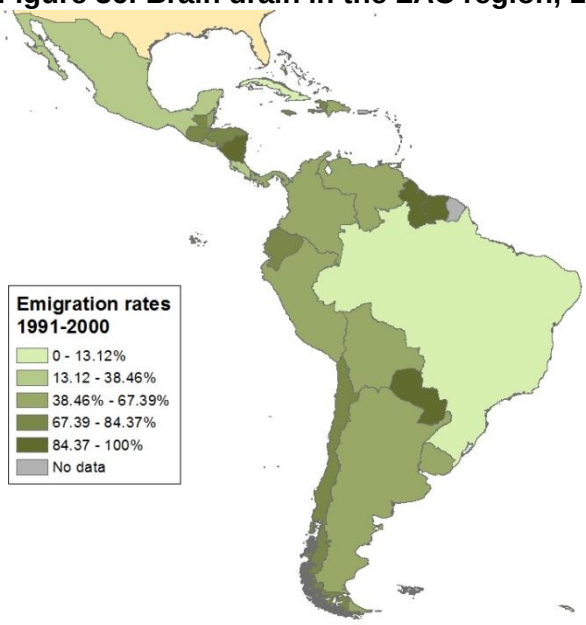


Figure 36a: Brain drain, 1991-2000

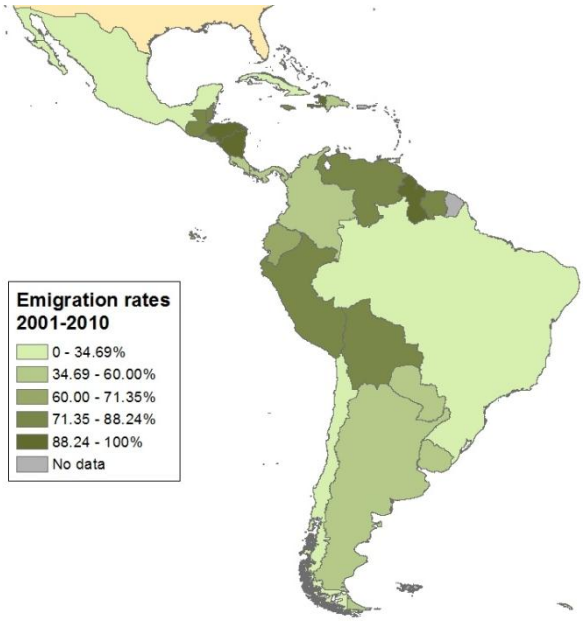


Figure 36b: Brain drain, 2001-2010

Figure 37 depicts the top-10 most popular destinations of Latin American inventors, whereby Europe is again treated as a whole. As for African inventor emigrants, the US and Europe lead the ranking. In relative terms, LAC inventors account for 3 percent of all immigrants in the US and for around 2 percent of all immigrants in Europe. However, the absolute number of Latin American migrant inventors going to the US is more than double that of inventors going to Europe. Unlike for African inventors, France does not lead the ranking within Europe; Germany does so, followed by Switzerland, Spain and France. The shared colonial past and common language explain why Span attracts considerable talent from LAC. Interestingly, 3 out of 10 countries in this ranking are from the region itself – Brazil, Mexico, and Chile.

Figure 38 further explores the destination of Latin American inventors for a small selection of countries. In line with what was mentioned above, the US dominates as a destination country.

Figure 37: Where do Latin American inventors go?

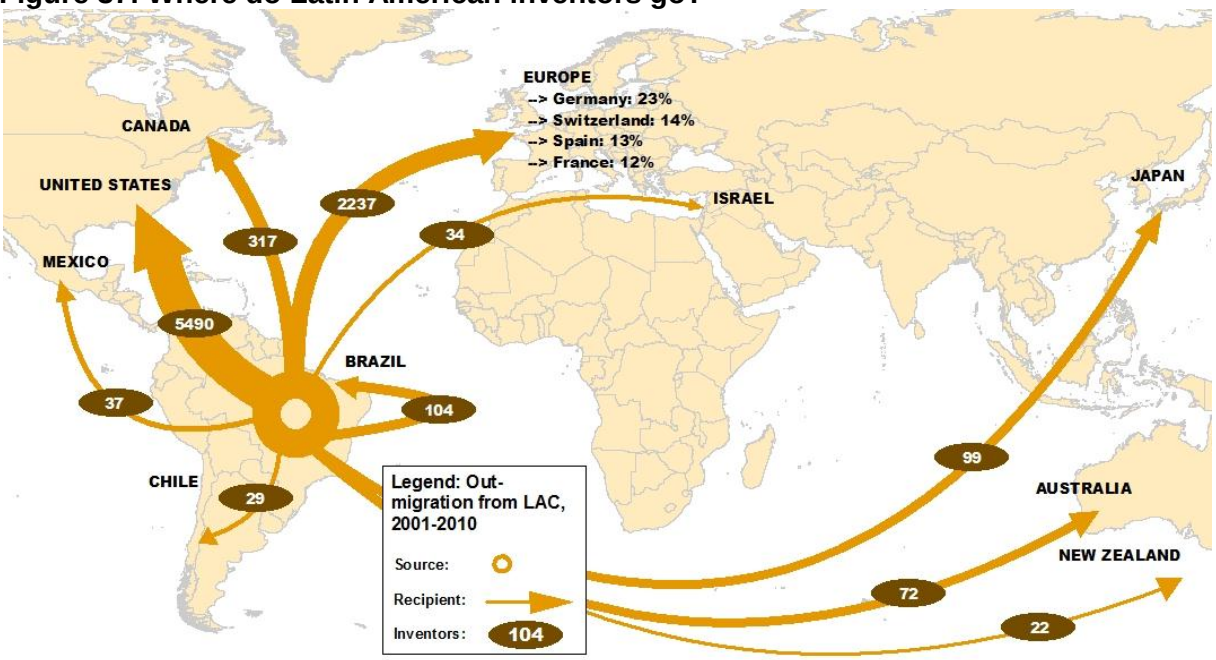
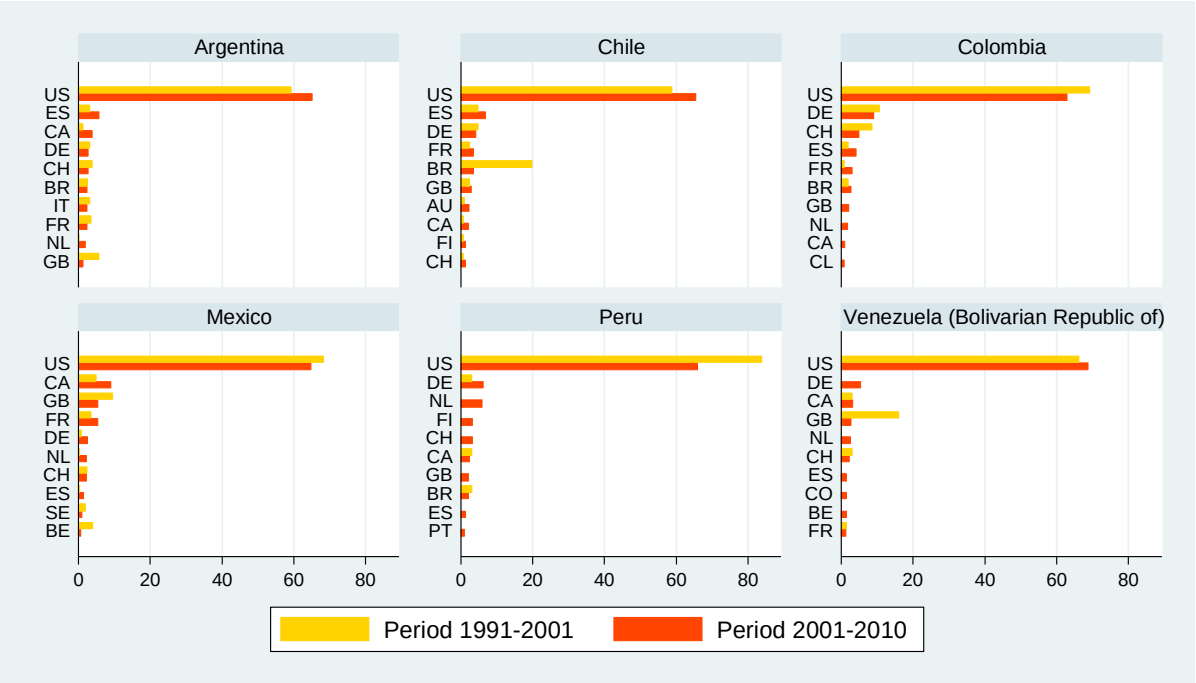


Figure 38: Most popular destinations of LAC inventors, selected countries



Note: Country codes in the vertical axes are AU: Australia, BE: Belgium, BR: Brazil, CA: Canada, CH: Switzerland, CL: Chile, CO: Colombia, DE: Germany, ES: Spain, FI: Finland, FR: France, GB: United Kingdom, IT: Italy, NL: the Netherlands, PT: Portugal, SE: Sweden, and US: United States.

Table 25 lists the largest migration corridors originating from LAC countries for the two time periods. Again, the US is the most frequently listed destination for inventors from the LAC region.

Table 25: Largest inventor migration corridors from LAC countries

Largest inventor migration corridors, 1991-2000			Largest inventor migration corridors, 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
Argentina	US	209	Mexico	US	1,161
Mexico	US	166	Brazil	US	1,115
Brazil	US	152	Argentina	US	820
Chile	US	94	Colombia	US	532
Colombia	US	72	Venezuela	US	405
Venezuela	US	41	Chile	US	251
Chile	Brazil	32	Peru	US	210
Brazil	Germany	26	Brazil	Germany	175
Peru	US	26	Mexico	Canada	164
Jamaica	US	26	Jamaica	US	142
Guyana	UK	26	Brazil	Switzerland	113
Brazil	UK	25	Ecuador	US	107
Argentina	Finland	23	Trinidad and Tobago	US	106
Mexico	UK	23	Mexico	UK	101
Brazil	France	21	Mexico	France	97
Cuba	US	21	Uruguay	US	84
Argentina	UK	21	Colombia	Germany	77
Ecuador	US	15	Guatemala	US	75
Costa Rica	US	14	Argentina	Spain	74
Argentina	Switzerland	14	Brazil	France	74
Argentina	France	13	Costa Rica	US	65
Uruguay	US	12	Brazil	UK	61
Mexico	Canada	12	Cuba	US	58
Argentina	Italy	12	Guyana	US	55
Guyana	US	12	Brazil	Japan	53
Argentina	Spain	12	Argentina	Canada	50
Argentina	Germany	12	Cuba	Germany	50
Colombia	Germany	11	Mexico	Germany	47
Mexico	Belgium	10	Cuba	Spain	44
Venezuela	UK	10	Brazil	Netherlands	44

Although smaller in numbers, it is also worth looking at intra-LAC inventor migration. Table 26 lists the top-10 most populated corridors, for which both origin and destination countries are from the LAC region. Brazil, similar to South Africa in the case of Africa, stands out in attracting the most regional talent, hosting more immigrants than any other country in the region.

However, like South Africa, Brazil sees a large number of national inventors emigrating abroad, becoming the LAC country with the biggest emigrant stock (Table 27). At the same time, Brazil's inventor brain drain rate remains modest compared to other countries in the region.

Table 26: Largest inventor migration corridors among LAC countries

Largest inventor migration corridors, 1991-2000			Largest inventor migration corridors, 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
Chile	Brazil	32	Argentina	Brazil	31
Argentina	Brazil	9	Colombia	Brazil	24
Venezuela	Mexico	3	Chile	Brazil	14
Argentina	Mexico	3	Argentina	Uruguay	12
Cuba	El Salvador	2	Argentina	Mexico	10
Ecuador	Mexico	2	Venezuela	Colombia	10
Argentina	Uruguay	2	Colombia	Chile	9
Colombia	Brazil	2	Colombia	Costa Rica	8
Peru	Brazil	1	Argentina	Chile	8
Uruguay	Brazil	1	Venezuela	Brazil	8

Table 27: Immigrant and emigrant stocks, 2001-2010

Country/territory	Immigrant stocks	Country/territory	Emigrant stocks
Brazil	376	Brazil	1,859
Mexico	164	Mexico	1,794
Bahamas	117	Argentina	1,259
Chile	115	Colombia	847
Argentina	100	Venezuela	589
Colombia	35	Chile	383
Costa Rica	33	Peru	318
Venezuela	32	Cuba	206
Barbados	25	Uruguay	163
Uruguay	25	Ecuador	150

Table 28 compares the performance of LAC inventors in their home countries to the performance of the LAC inventor diaspora. For all countries except Venezuela, the diaspora receives more citations, on average, than the local pool of inventors, possibly indicating that the more talented inventors are more likely to migrate.

Table 28: Citations received by nationals-residents vs. diaspora

	Average citation received by nationals in home country	Average citations received by emigrants	Significance difference
Brazil	0.59	0.98	t-statistic=9.23*** p-value=0.000
Mexico	0.44	1.52	t-statistic=16.42*** p-value=0.000
Argentina	0.99	1.61	t-statistic=4.59*** p-value=0.000
Colombia	0.23	1.11	t-statistic=7.16*** p-value=0.000
Venezuela	1.04	0.84	t-statistic=0.91 p-value= 0.362
Chile	0.36	2.01	t-statistic=9.65*** p-value=0.000
Peru	0.34	1.24	t-statistic=2.92*** p-value=0.001
Cuba	0.57	1.19	t-statistic=5.26*** p-value=0.000
Uruguay	0.79	1.25	t-statistic=2.05** p-value= 0.041
Ecuador	0.40	1.20	t-statistic=2.41** p-value= 0.017

Note: ***, **, and * indicates significance at 1, 5, and 10 percent levels respectively.

6.3. A closer look at the Middle East, South Asia, East Asia and Oceania and the Pacific

This section takes a closer look at countries from the Middle East, South and East Asia, and Oceania and the Pacific. Figure 39 depicts the brain drain of inventors for the 2001-2010 period in these regions. As can be seen, some countries in the Middle East (except Saudi Arabia) and South and East Asia (except China) seem the most affected by the brain drain of inventors. By contrast, Australia, the Republic of Korea and Japan show the lowest emigration rates.

Figure 39: Brain drain in the Middle East, South Asia, East Asia and Oceania and the Pacific, 2001-2010

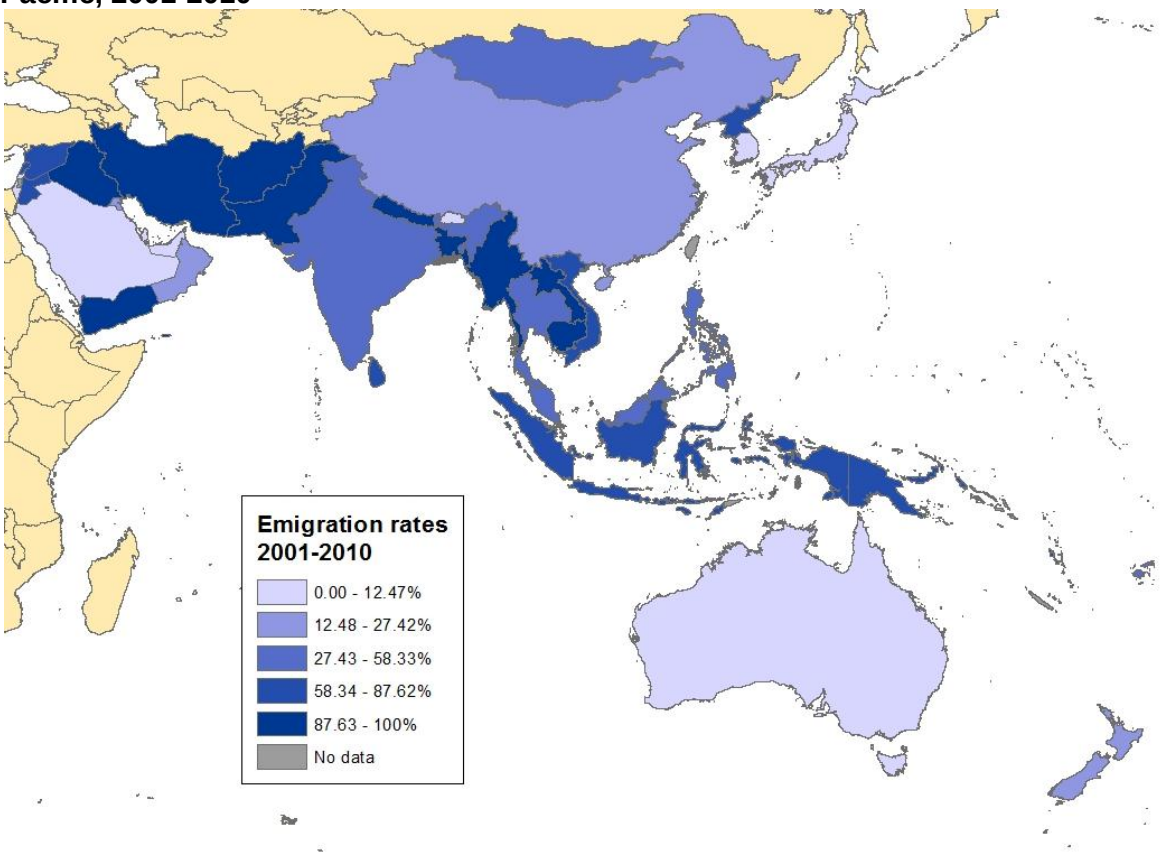


Figure 40 depicts the top-10 most popular destinations of inventors from these regions, with Europe treated as a whole. Compared to the LAC region and especially Africa, the absolute number of emigrant inventors from the Middle East, South and East Asia, Oceania and the Pacific is considerably larger. There are two main features that characterize emigration of inventors from these regions. First, the proportion of inventors going to the US as compared to other world regions is large. For example, there are nine times as many migrant inventors from this area emigrating to the US than emigrating to Europe. They represent 54.4 percent of all immigrant inventors in the US for the period 2001-2010 – substantially larger than the immigrant shares of African and LAC inventors in the US. China and India's migration flows to the US largely explain this outcome, although other countries also play a role. Second, countries from the same region feature among the top-10 destinations. In particular, Japan, Australia, New Zealand, Singapore, the Republic of Korea, China and Malaysia attract large numbers of inventors from the region. In addition, within Europe, the UK receives up to 30 percent of inventors from these countries and leads the ranking – in contrast to France and Germany assuming the lead position for African and LAC inventors, respectively.

Figure 41 further explores the destination of inventors from this region for a small selection of countries. Again, the US dominates as a destination country for all the countries shown.

Figure 40: Where do inventors from the Middle East, South Asia, East Asia as well as Oceania and the Pacific go?

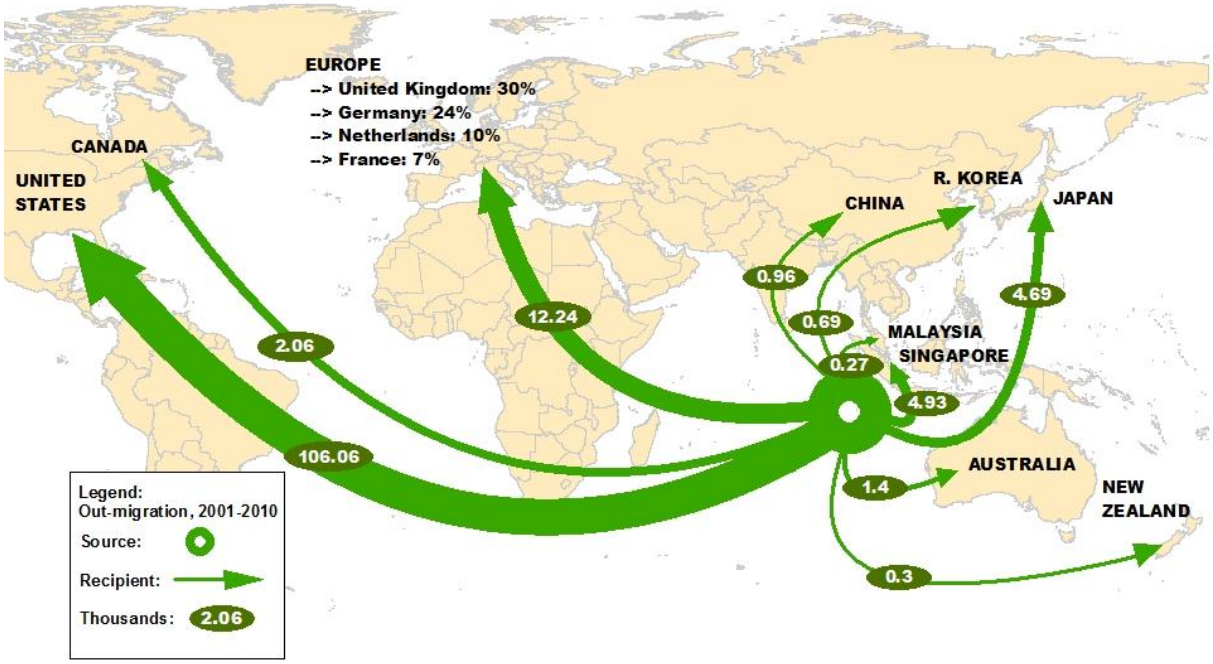
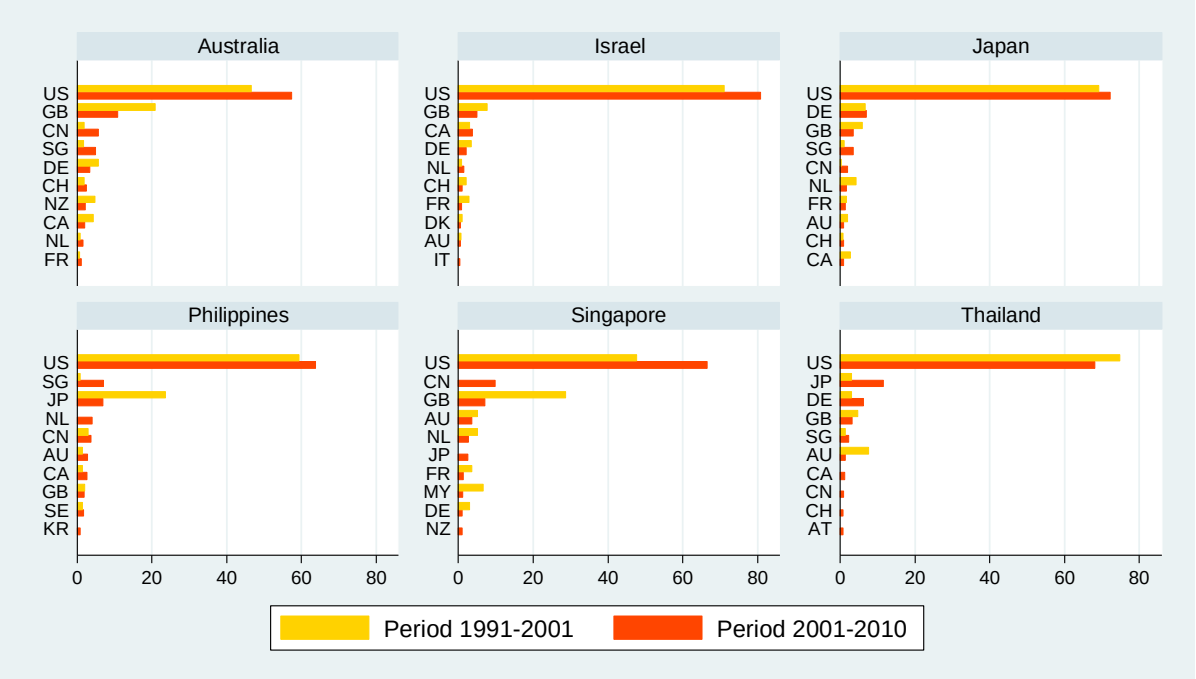


Figure 41: Most popular destinations of inventors, selected countries



Note: Country codes in the vertical axes are AT: Austria, AU: Australia, CA: Canada, CH: Switzerland, CN: China, DE: Germany, DK: Denmark, FR: France, GB: United Kingdom, IT: Italy, JP: Japan, KR: the Republic of Korea, MY: Malaysia, NL: the Netherlands, NZ: New Zealand, SE: Sweden, SG: Singapore, and US: United States.

Table 29 presents the largest migration corridors originating from countries of the Middle East, South and East Asia, and Oceania and the Pacific. Again, by and large, the US appears as the most frequently listed destination. Interestingly, especially given its small size, Singapore emerges as a regional hub in attracting talent from the region.

Table 29: Largest inventor migration corridors from the Middle East, South Asia, East Asia and Oceania and the Pacific

Largest inventor migration corridors, 1991-2000			Largest inventor migration corridors, 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
China	US	6,279	China	US	44,452
India	US	4,470	India	US	35,621
Japan	US	857	R. of Korea	US	7,267
Australia	US	569	Japan	US	5,045
R. of Korea	US	546	Australia	US	3,241
Israel	US	522	Israel	US	2,966
China	Japan	402	China	Japan	2,510
China	UK	328	China	Singapore	1,923
China	Germany	311	Iran	US	1,438
New Zealand	Australia	273	Malaysia	Singapore	1,090
Australia	UK	255	R. of Korea	Japan	1,080
Iran	US	233	China	UK	920
Iran	Germany	204	China	Germany	892
China	Canada	203	India	Singapore	847
China	Singapore	181	Singapore	US	775
New Zealand	US	163	Malaysia	US	729
China	Australia	135	New Zealand	US	678
India	Japan	123	China	Canada	652
India	UK	121	Pakistan	US	626
Malaysia	US	114	Australia	UK	609
R. of Korea	Japan	112	India	UK	556
China	Sweden	111	India	Germany	542
India	Canada	110	New Zealand	Australia	537
India	Singapore	108	Japan	Germany	502
Malaysia	Singapore	100	Thailand	US	494
New Zealand	UK	98	Philippines	US	450
Pakistan	US	86	India	Canada	440
Japan	Germany	83	Indonesia	US	421
Lebanon	US	82	Bangladesh	US	380
China	France	82	Lebanon	US	363

Table 30 lists the top-10 most populated corridors, when both origin and destination countries are from this region. Again, Singapore is the most named destination country in both periods; for the1991-2000 period, Singapore shares the lead position with Japan.

Indeed, Singapore receives the largest number of inventor immigrants in 2001-2010, followed by Japan, Australia and China (see Table 31). The rankings of immigrants and emigrants for the case of the Middle East, South and East Asia, Oceania and the Pacific are less similar between them (see the last columns of Table 31).

Table 30: Largest inventor migration corridors among inventors from Middle East, South Asia, East Asia as well as Oceania and the Pacific

Largest inventor migration corridors, 1991-2000			Largest inventor migration corridors, 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
China	Japan	402	China	Japan	2,510
New Zealand	Australia	273	China	Singapore	1,923
China	Singapore	181	Malaysia	Singapore	1,090
China	Australia	135	R. of Korea	Japan	1,080
India	Japan	123	India	Singapore	847
R. of Korea	Japan	112	New Zealand	Australia	537
India	Singapore	108	China	R. of Korea	334
Malaysia	Singapore	100	Australia	China	327
Australia	New Zealand	59	India	Japan	319
Malaysia	Australia	52	Australia	Singapore	278

Table 31: Immigrant and emigrant stocks, 2001-2010

Country/territory	Immigrant stocks	Country/territory	Emigrant stocks
Singapore	6,720	China	53,610
Japan	6,715	India	40,097
Australia	4,427	Republic of Korea	9,127
China	4,251	Japan	6,986
Republic of Korea	1,472	Australia	5,631
New Zealand	1,249	Israel	3,668
Israel	694	Malaysia	2,682
Saudi Arabia	569	Iran	2,253
India	532	New Zealand	1,839
Malaysia	524	Singapore	1,166

Table 32 compares the citation performance of national-resident inventors to the performance of the inventor diaspora for countries in the Middle East, South and East Asia, Oceania and the Pacific. For all cases except Israel, the diaspora receives on average more citations than the local pool of inventors, possibly indicating that the most talented inventors emigrate. In the case of Israel, the difference in the performance between local inventors and the Israeli diaspora is statistically significant, but – interestingly – domestic inventors are more cited than nationals residing abroad.

Table 32: Citations received by nationals-residents vs. diaspora

	Average citation received by nationals in home country	Average citations received by emigrants	Significance difference
China	0.20	1.85	t-statistic=126.95*** p-value=0.000
India	1.16	1.34	t-statistic=9.51*** p-value=0.000
R. of Korea	0.64	1.22	t-statistic=29.83*** p-value=0.000
Japan	0.88	1.35	t-statistic=18.74*** p-value=0.000
Australia	1.24	1.65	t-statistic=12.19*** p-value=0.000
Israel	1.34	1.16	t-statistic=-4.55*** p-value=0.000
Malaysia	0.31	1.03	t-statistic=17.46*** p-value=0.000
Iran	0.58	1.16	t-statistic=2.06** p-value=0.039
New Zealand	1.17	1.53	t-statistic=6.70*** p-value=0.000
Singapore	0.77	0.86	t-statistic=1.80* p-value=0.072

Note: ***, **, and * indicates significance at 1, 5, and 10 percent levels respectively.

6.4. A closer look at Europe and Central Asia

Finally, this section takes a closer look at the international mobility of inventors for countries in Europe and Central Asia. Figure 42 depicts the region's brain drain rates, showing that countries from Eastern Europe – especially the Balkans – and Central Asia are the ones most affected by the brain drain of inventors.

Figure 42: Brain drain in Europe and Central Asia, 2001-2010

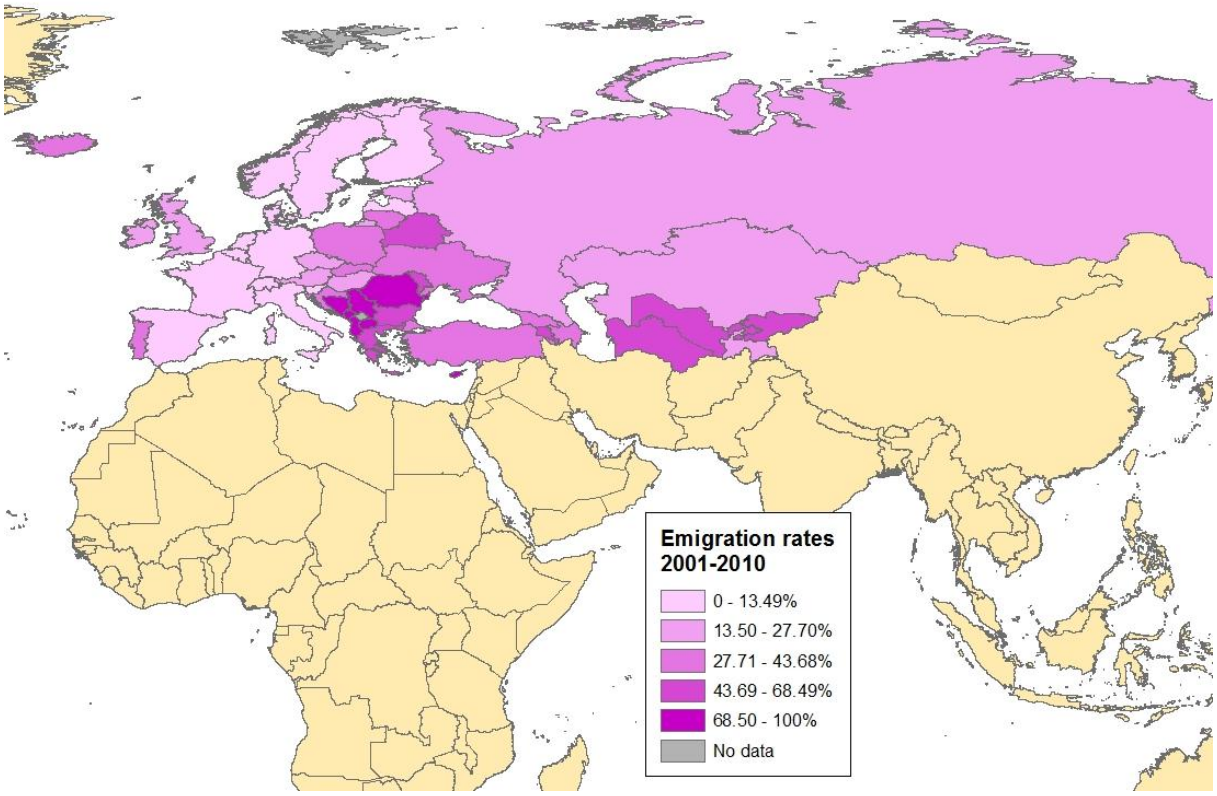


Figure 43 depicts the top-10 most popular destinations of inventors from Europe and Central Asia. Different from the other regions analyzed, the majority of migrant inventors from these countries do not move to the US, but stay in Europe and Central Asia – with most of them moving specifically within and to Western Europe. The US ranks second in attracting talent from this region, accounting for 31 percent of all immigrants in the US. The high income status of Western Europe, language ties, and the opening of Western European labor markets may explain the large intra-regional inventor flows.

Interestingly, when exploring the most popular individual destination countries for selected European and Central Asian countries, the US remains the preferred destination for most origin countries (see Figure 44 and also Figure 21).

Figure 43: Where do inventors from Europe and Central Asia go?

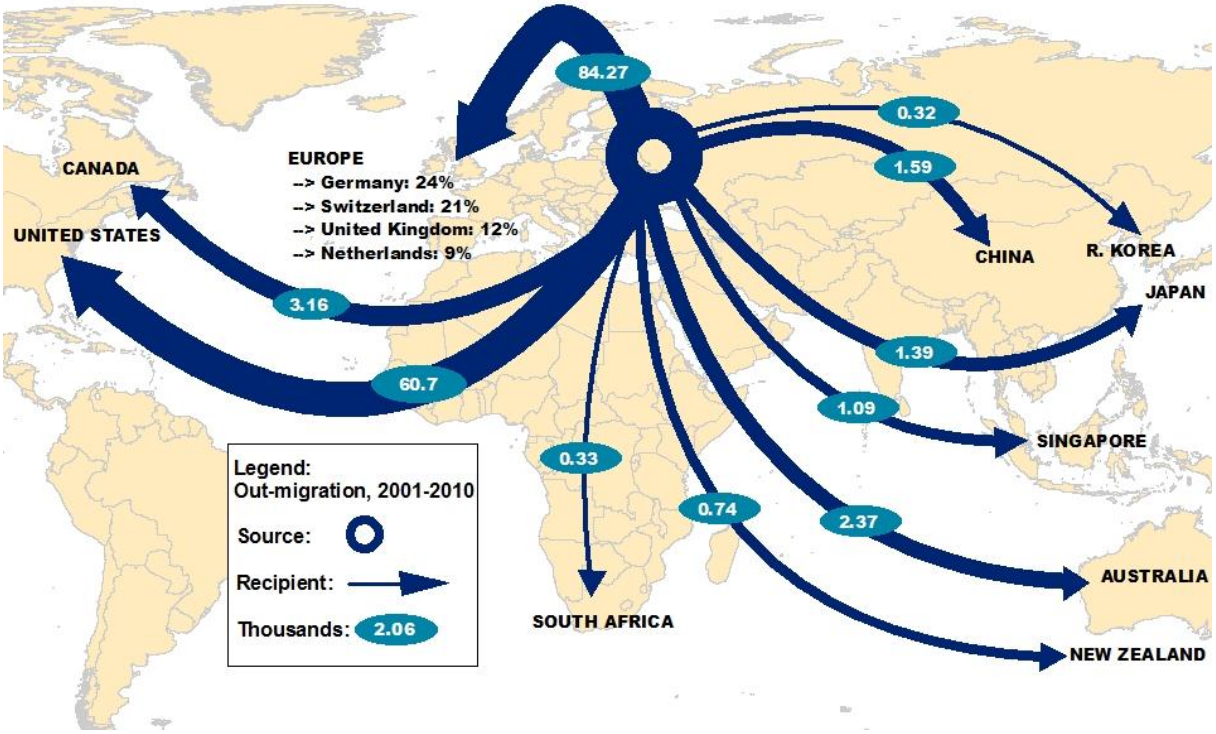
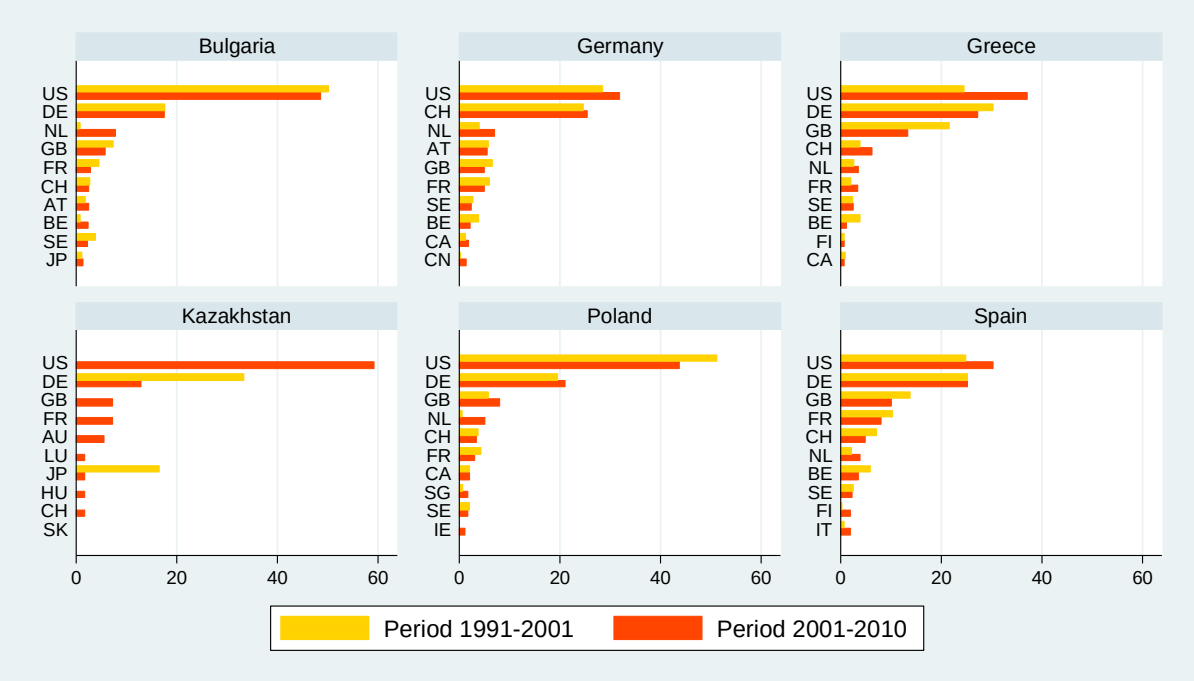


Figure 44: Most popular destinations of inventors, selected countries



Note: Country codes in the vertical axes are AT: Austria, AU: Australia, BE: Belgium, CA: Canada, CH: Switzerland, CN: China, DE: Germany, FI: Finland, FR: France, GB: United Kingdom, HU: Hungary, IE: Ireland, IT: Italy, JP: Japan, LU: Luxemburg, NL: the Netherlands, RW: Rwanda, SE: Sweden, SG: Singapore, and US: United States.

Table 33 lists the most populated corridors originating from Europe and Central Asia. The US features as a destination country in most of these corridors and most origins are Western European countries

Table 34 repeats the analysis but excludes high income economies as inventor origins. It shows that, although the US continues to be the preferred destination in most of the cases, it only features 9 times in the 2001-2010 period; by comparison, in Table 33 the US features as destination in 12 out of 30 cases in the 2001-2010 period. As for inventor origins, Russia, followed by Romania dominate.

Table 33: Largest inventor migration corridors from Europe and Central Asia

Largest inventor migration corridors, 1991-2000			Largest inventor migration corridors 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
UK	US	4,249	UK	US	14,893
Germany	US	2,055	Germany	US	10,297
Germany	Switzerland	1,786	Germany	Switzerland	8,198
Austria	Germany	1,362	France	US	6,543
France	US	1,003	Russia	US	4,339
Russia	US	842	France	Switzerland	2,747
UK	Germany	780	Netherlands	US	2,698
UK	Australia	576	Austria	Germany	2,672
France	UK	513	France	Germany	2,607
Germany	UK	476	Italy	US	2,501
UK	France	435	Germany	Netherlands	2,285
Germany	France	432	Netherlands	Germany	2,138
Switzerland	US	431	France	UK	2,044
Italy	US	430	UK	Germany	2,043
Germany	Austria	429	Turkey	US	1,922
Sweden	US	426	Germany	Austria	1,829
Netherlands	US	420	Germany	UK	1,612
Ireland	UK	419	Germany	France	1,609
Italy	Germany	416	Spain	US	1,559
France	Switzerland	406	UK	Switzerland	1,555
France	Germany	403	Italy	Switzerland	1,536
Netherlands	Germany	384	Italy	Germany	1,529
Belgium	France	373	UK	Netherlands	1,456
UK	Switzerland	355	Sweden	US	1,452
UK	Canada	352	Switzerland	US	1,348
Italy	Switzerland	340	France	Belgium	1,347
France	Belgium	330	Spain	Germany	1,298
UK	Belgium	328	Romania	US	1,220
UK	Netherlands	304	Russia	Germany	1,207
Germany	Netherlands	296	Greece	US	1,190

Table 34: Largest inventor migration corridors from Europe and Central Asia. Origin non-high income economies

Largest inventor migration corridors, 1991-2000			Largest inventor migration corridors, 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
Russia	US	842	Russia	US	4,339
Russia	Germany	187	Turkey	US	1,922
Turkey	US	178	Romania	US	1,220
Bulgaria	US	128	Russia	Germany	1,207
Ukraine	US	126	Ukraine	US	977
Turkey	Germany	118	Bulgaria	US	626
Russia	UK	85	Turkey	Germany	601
Romania	US	65	Ukraine	Germany	416
Russia	Canada	57	Serbia	US	384
Ukraine	Germany	55	Russia	UK	337
Russia	Sweden	54	Romania	Germany	264
Russia	Switzerland	51	Romania	Netherlands	238
Russia	France	47	Russia	Sweden	231
Bulgaria	Germany	45	Bulgaria	Germany	226
Russia	Finland	44	Belarus	US	207
Romania	UK	41	Russia	Finland	204
Russia	Hungary	40	Russia	France	194
Turkey	UK	32	Russia	Netherlands	186
Russia	Spain	30	Russia	Switzerland	168
Russia	Australia	29	Russia	Canada	152
Ukraine	UK	24	Romania	Finland	150
Russia	Netherlands	22	Romania	France	142
Turkey	Switzerland	21	Russia	R. of Korea	122
Romania	France	21	Turkey	Netherlands	117
Bulgaria	UK	19	T F Y R of Macedonia	US	103
Russia	Israel	19	Bulgaria	Netherlands	102
Kyrgyzstan	Switzerland	17	Romania	UK	102
Latvia	Sweden	16	Romania	Ireland	101
Russia	Italy	16	Bosnia and Herzegovina	US	100
Ukraine	Canada	15	Belarus	Netherlands	97

Note: Income groups according to the World Bank classification of 2012.

Table 35 focuses on intra-mobility among European and Central Asian countries. Most inventor migration occurs among Western European countries, with geographical and cultural proximity seemingly exerting a role. The bottom panel of Table 35 looks only at cases where the origin country is not a high income economy. Again, Russia and Romania are important inventor origins, as is Turkey when Germany is the destination.

As in the cases of Africa and the LAC region, almost the same countries rank high both in terms of immigrant and emigrant stocks of inventors (see Table 36). Exceptions are the large immigrant populations in Switzerland, Finland and Denmark – unmatched by those countries' emigrant population – and the large inventor diaspora from Italy, Russia and Spain.

Table 35: Largest inventor migration corridors among inventors from Europe and Central Asia

Largest inventor migration corridors, 1991-2000			Largest inventor migration corridors, 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
Germany	Switzerland	1,786	Germany	Switzerland	8,198
Austria	Germany	1,362	France	Switzerland	2,747
UK	Germany	780	Austria	Germany	2,672
France	UK	513	France	Germany	2,607
Germany	UK	476	Germany	Netherlands	2,285
UK	France	435	Netherlands	Germany	2,138
Germany	France	432	France	UK	2,044
Germany	Austria	429	UK	Germany	2,043
Ireland	UK	419	Germany	Austria	1,829
Italy	Germany	416	Germany	UK	1,612
Migration corridors from low and middle income countries					
Origin	Destination	Counts	Origin	Destination	Counts
Russia	Germany	187	Russia	Germany	1,207
Turkey	Germany	118	Turkey	Germany	601
Russia	UK	85	Ukraine	Germany	416
Ukraine	Germany	55	Russia	UK	337
Russia	Sweden	54	Romania	Germany	264
Russia	Switzerland	51	Romania	Netherlands	238
Russia	France	47	Russia	Sweden	231
Bulgaria	Germany	45	Bulgaria	Germany	226
Russia	Finland	44	Russia	Finland	204
Romania	UK	41	Russia	France	194

Note: Income groups according to the World Bank classification of 2012.

Table 36: Immigrant and emigrant stocks, , 2001-2010

Country/territory	Immigrant stocks	Country/territory	Emigrant stocks
Germany	25,341	Germany	32,158
Switzerland	20,416	United Kingdom	27,746
United Kingdom	15,758	France	19,123
Netherlands	9,665	Italy	9,820
France	9,540	Netherlands	9,132
Belgium	5,042	Russian Federation	7,878
Sweden	4,832	Spain	5,154
Austria	3,113	Austria	5,122
Finland	3,095	Sweden	4,025
Denmark	2,589	Belgium	3,567

Table 37 looks at the citations received by national-resident inventors compared to those received by the inventor diaspora. Given that the countries in Europe and Central Asia with the largest stock of emigrants are already shown in Table 16, Table 37 provides a different selection of countries. For all the cases, the diaspora of inventors tend to be cited more often than their national counterparts and the differences are statistically significant.

Table 37: Citations received by nationals-residents vs. diaspora

	Average citation received by nationals in home country	Average citations received by emigrants	Significance difference
Spain	0.77	1.65	t-statistic=27.07*** p-value=0.000
Austria	0.93	1.31	t-statistic=13.73*** p-value=0.000
Sweden	1.31	1.41	t-statistic=2.79*** p-value=0.005
Belgium	1.48	1.58	t-statistic=2.21** p-value=0.027
Greece	0.84	1.51	t-statistic=8.55*** p-value=0.000
Switzerland	1.44	1.83	t-statistic=7.59*** p-value=0.000
Ireland	1.23	1.75	t-statistic=8.27*** p-value=0.000
Poland	0.80	1.30	t-statistic=9.36*** p-value=0.000
Denmark	1.85	1.64	t-statistic=3.18** p-value=0.002
Finland	1.50	1.78	t-statistic=3.79*** p-value=0.000

Note: ***, **, and * indicates significance at 1, 5, and 10 percent levels respectively.

7. CONCLUSIONS AND IMPLICATIONS

This report describes a new global dataset on migrant inventors, using information on inventor nationality and residence available in PCT applications. By using patent data to map the migratory patterns of high-skilled workers, one can overcome some of the limitations faced by existing migration datasets.

In particular, this database, which covers a long time period, provides information on an annual basis, and includes a large number of sending and receiving countries. Inventors constitute a group of high-skilled workers of special economic importance and with more homogenous skills than tertiary-educated workers as a whole.

Using unit record data, it is also possible to link patent-inventor data with citation and co-inventorship information, and study social relationships between inventors and subsequent knowledge diffusion patterns. In addition, patent data offers information on inventors' fields of expertise as revealed through the technology classes listed in their patents. This can help overcome one limitation of traditional migration datasets, namely the lack of information on high-skilled migrants' specific skills.

The inventor migration dataset presented here relies on the PCT system, which applies a uniform set of procedural rules worldwide and which has close to universal coverage – promoting the cross-country comparability of data. In addition, patents filed under the PCT system are likely to include the most valuable inventions, as revealed in the willingness of applicants to potentially bear the patenting costs in multiple jurisdictions.

Of course, using patent data for economic analysis does not come without limitations. One important caveat is that one only observes inventors when they seek patents. However, not all inventions are patented; indeed, the propensity to patent for each dollar invested in

research and development differs considerably across industries.[38] In addition, there is no one-for-one correspondence between the number of patent applications filed and the commercial value of the underlying inventions or their contribution to technological progress. Studies have documented a skewed distribution of patent values, with relatively few patents yielding high economic returns.[39] Similarly, the propensity to patent abroad – and in particular through the PCT route – differs across countries, affecting the selection of inventors included in the data.

As it is the case for most other migration datasets, patent data can only identify inventors with migratory background, but do not reveal where those inventors were educated. Anecdotal evidence suggests, for example, that many immigrant inventors in the US received scientific degree from US universities – although such cases may still involve a "drain of brains". Another limitation is that the dataset misses inventors with migratory background that have become nationals of their host country. To the extent that it is easier to gain citizenship in some countries than in others, this introduces a bias in the data. A related bias stems from the possibility that migrants of some origins may be more inclined to adopt the host country's nationality than migrants from other origins. Unfortunately, the data do not allow for an assessment of how severe these biases are. Researchers using these data should be aware of these limitations, especially when drawing policy conclusions.

Notwithstanding these caveats, this new database meaningfully captures a phenomenon of growing importance. Indeed, the descriptive overview presented in this report suggests that it is consistent with migratory patterns and trends as they emerge from census data. At the same time, the database opens new avenues for research, promising to generate fresh empirical insights that can inform both innovation policy and migration policy.

[38] See Hall and Ziedonis (2001) and WIPI 2011 special theme (WIPO 2011).
[39] See Hall et al. (2005).

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Appendix 1: Data coverage, by country

Figure A.1.: Coverage of nationality and residence information, selected countries

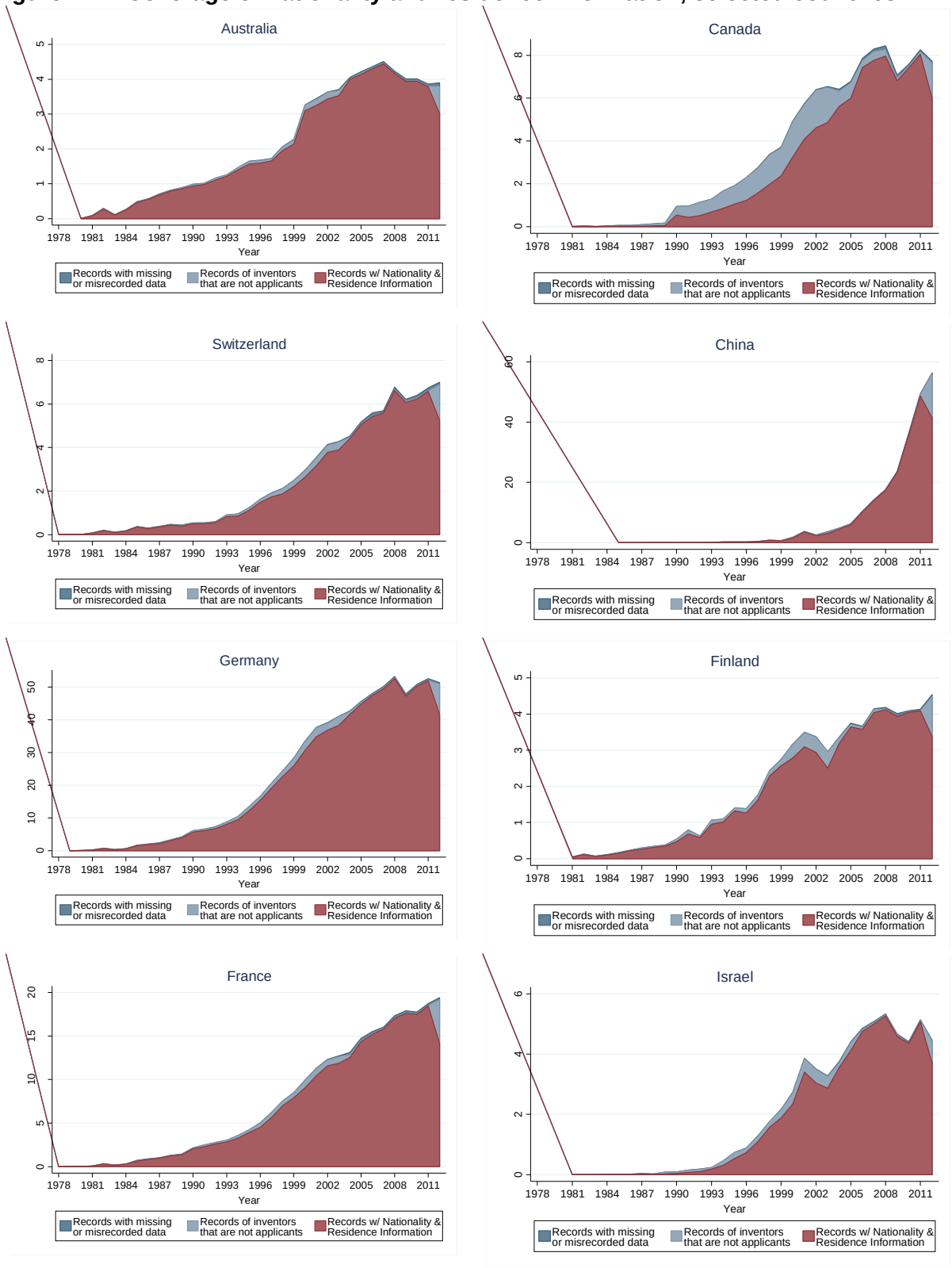
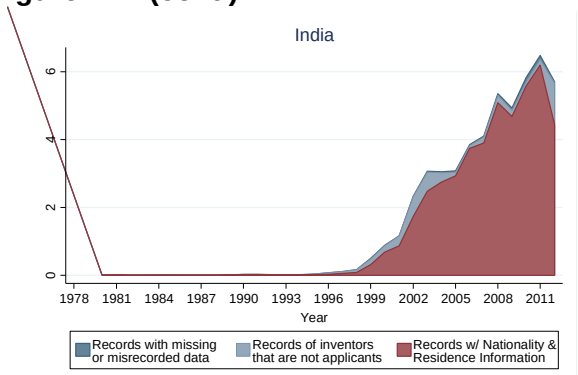
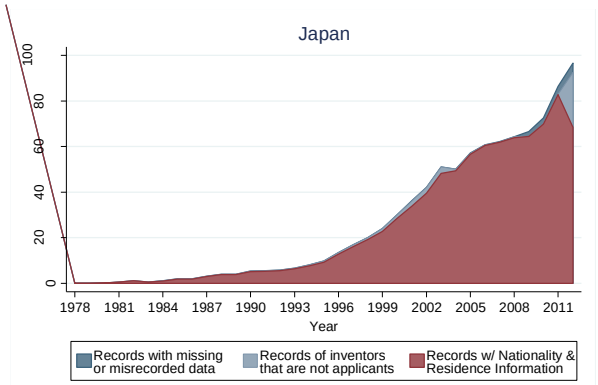
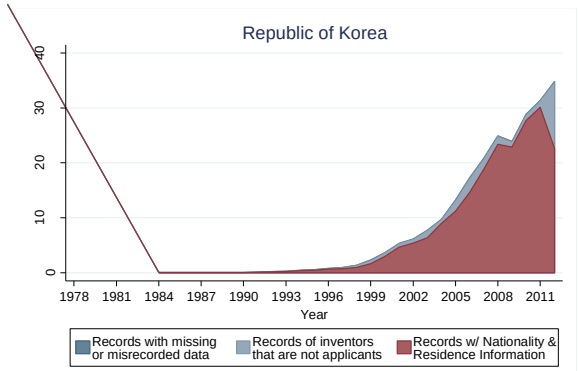
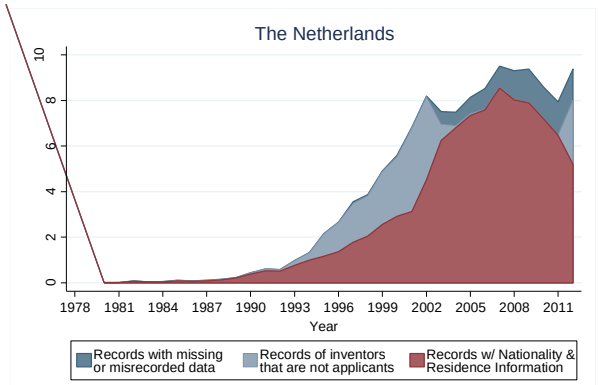


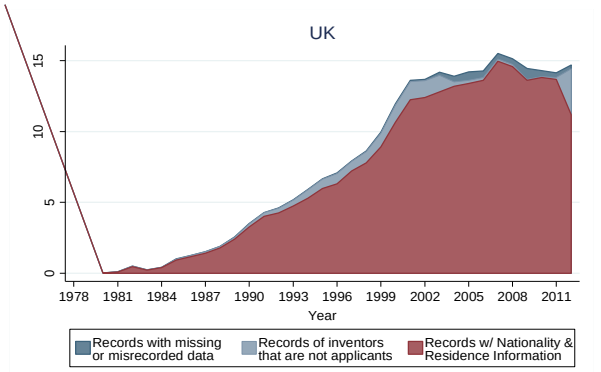
Figure A.1. (cont.)

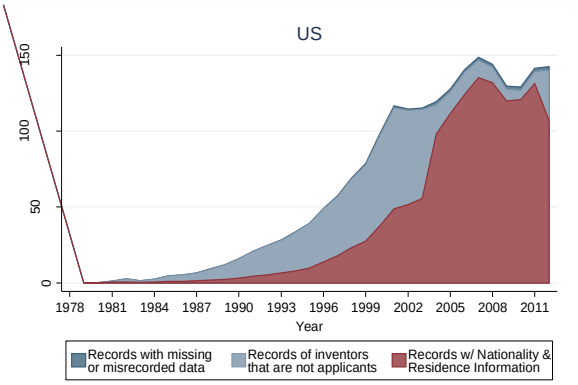


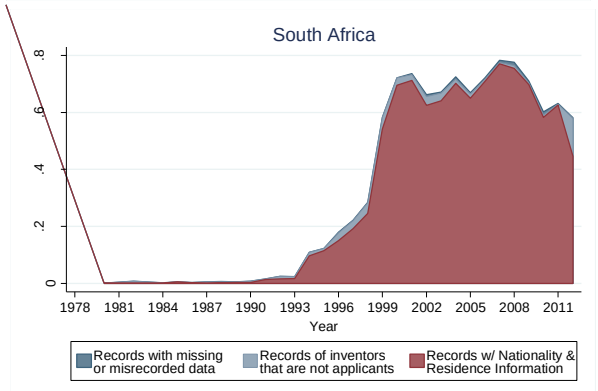












Appendix 2: Evolution of migrant inventors

Table A1: Evolution of migrant inventors, by records and by patents

Year	Total Records	Migrant records	Total patents	Migrant patents
1978	26	3	12	2
1979	44	3	31	2
1980	1,393	59	769	54
1981	5,465	262	3,198	234
1982	2,425	109	1,448	100
1983	3,545	177	2,043	149
1984	8,703	420	4,751	342
1985	10,121	446	5,478	390
1986	12,395	490	6,381	408
1987	16,324	718	8,233	593
1988	19,914	913	9,917	767
1989	26,435	1,199	12,798	1,024
1990	30,155	1,461	14,641	1,250
1991	33,334	1,751	15,954	1,449
1992	40,405	2,357	18,968	1,855
1993	46,958	2,770	22,050	2,239
1994	55,931	3,719	25,974	2,955
1995	70,523	4,710	31,791	3,576
1996	89,027	6,270	39,918	4,748
1997	106,380	7,955	47,438	5,904
1998	124,236	9,546	55,336	6,949
1999	155,532	12,578	68,276	8,949
2000	190,940	16,447	82,990	11,117
2001	206,618	18,905	87,833	12,427
2002	224,824	19,512	95,538	13,348
2003	284,383	27,832	121,287	18,883
2004	321,526	32,137	137,948	21,744
2005	354,289	36,601	152,111	24,593
2006	384,447	39,810	165,140	27,023
2007	403,531	40,948	171,578	27,536
2008	387,344	39,757	161,724	26,305
2009	407,806	40,608	168,443	26,920
2010	448,063	44,323	184,230	29,250
2011	400,282	38,785	101,933	15,784
2012	67,057	5,803	311	20
Total	**4,940,381**	**459,384**	**2,026,471**	**298,889**

Appendix 3: Immigrants, emigrants and emigration rates, all countries
Table A2: Immigrants, emigrants and emigration rates, 1991-2000

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Afghanistan	0	0	0	3	1.00
Åland Islands	0	0	0	0	
Albania	0	2	2	12	0.86
Algeria	1	10	11	126	0.92
American Samoa	0	0	0	0	
Andorra	13	1	14	1	0.07
Angola	0	0	0	0	
Anguilla	0	0	0	0	
Antigua and Barbuda	0	1	1	12	0.92
Argentina	30	192	222	353	0.61
Armenia	1	48	49	26	0.35
Aruba	0	0	0	0	
Australia	2,051	16,791	18,842	1,224	0.06
Austria	720	7,459	8,179	1,993	0.20
Azerbaijan	1	16	17	4	0.19
Bahamas (the)	71	2	73	1	0.01
Bahrain	0	1	1	1	0.50
Bangladesh	1	0	1	103	0.99
Barbados	3	1	4	2	0.33
Belarus	3	296	299	39	0.12
Belgium	1,760	8,661	10,421	1,235	0.11
Belize	1	0	1	2	0.67
Benin	1	0	1	4	0.80
Bermuda	0	0	0	0	
Bhutan	0	0	0	0	
Bolivia (Plurinational State of)	2	5	7	10	0.59
Bonaire, Sint Eustatius and Saba	0	0	0	0	
Bosnia and Herzegovina	0	17	17	32	0.65
Botswana	0	1	1	1	0.50
Brazil	168	1,541	1,709	258	0.13
British Virgin Islands	0	0	0	0	
Brunei Darussalam	1	0	1	1	0.50
Bulgaria	5	347	352	255	0.42
Burkina Faso	0	1	1	1	0.50
Burundi	0	2	2	0	0.00
Cambodia	0	0	0	5	1.00
Cameroon	0	5	5	48	0.91
Canada	1,943	15,467	17,410	3,286	0.16
Cape Verde	0	0	0	0	
Cayman Islands	0	0	0	0	
Central African Republic (the)	0	0	0	0	
Chad	0	1	1	0	0.00
Chile	11	50	61	160	0.72
China	249	6,526	6,775	8,206	0.55
China, Hong Kong SAR	12	0	12	11	0.48
China, Macao SAR	0	0	0	0	
Colombia	9	47	56	104	0.65
Comoros (the)	0	0	0	0	
Congo (the)	0	1	1	5	0.83
Cook Islands (the)	2	0	2	0	0.00
Costa Rica	9	15	24	15	0.38
Côte d'Ivoire	3	4	7	6	0.46
Croatia	13	290	303	174	0.36
Cuba	5	300	305	35	0.10

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Curaçao	0	0	0	0	
Cyprus	32	14	46	58	0.56
Czech Republic	26	863	889	174	0.16
Czechoslovakia	0	140	140	34	0.20
Democratic People's Republic of Korea (the)	0	18	18	12	0.40
Democratic Republic of the Congo (the)	0	0	0	6	1.00
Denmark	547	10,247	10,794	701	0.06
Djibouti	0	0	0	0	
Dominica	1	0	1	3	0.75
Dominican Republic (the)	4	0	4	6	0.60
Ecuador	3	2	5	27	0.84
Egypt	11	28	39	137	0.78
El Salvador	4	4	8	9	0.53
Equatorial Guinea	0	0	0	0	
Eritrea	0	0	0	7	1.00
Estonia	7	86	93	32	0.26
Ethiopia	0	0	0	26	1.00
Faeroe Islands	0	0	0	0	
Falkland Islands (Malvinas)	0	0	0	0	
Fiji	5	1	6	5	0.45
Finland	501	16,610	17,111	561	0.03
France	2,909	53,934	56,843	3,350	0.06
French Guiana	0	0	0	0	
French Polynesia	0	0	0	0	
Gabon	1	1	2	3	0.60
Gambia (the)	6	0	6	0	0.00
Georgia	1	58	59	24	0.29
Germany	6,887	176,311	183,198	7,216	0.04
Ghana	0	5	5	52	0.91
Gibraltar	0	0	0	0	
Greece	34	597	631	770	0.55
Greenland	0	0	0	0	
Grenada	0	0	0	7	1.00
Guadeloupe	0	0	0	0	
Guam	0	0	0	0	
Guatemala	2	1	3	14	0.82
Guernsey	0	0	0	0	
Guinea	0	0	0	2	1.00
Guinea-Bissau	0	0	0	1	1.00
Guyana	0	0	0	39	1.00
Haiti	1	0	1	5	0.83
Holy See (the)	0	0	0	0	
Honduras	0	2	2	6	0.75
Hungary	72	3,779	3,851	377	0.09
Iceland	3	188	191	113	0.37
India	14	1,538	1,552	5,193	0.77
Indonesia	20	52	72	88	0.55
Iran (Islamic Republic of)	2	18	20	604	0.97
Iraq	0	0	0	73	1.00
Ireland	407	1,935	2,342	906	0.28
Isle of Man	0	0	0	0	
Israel	439	11,299	11,738	733	0.06
Italy	719	17,795	18,514	2,068	0.10
Jamaica	1	6	7	36	0.84
Japan	1,376	156,488	157,864	1,237	0.01

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Jersey	0	0	0	0	
Jordan	0	8	8	70	0.90
Kazakhstan	7	99	106	6	0.05
Kenya	5	5	10	21	0.68
Kiribati	0	0	0	0	
Kuwait	6	2	8	4	0.33
Kyrgyzstan	1	5	6	21	0.78
Lao People's Democratic Republic (the)	0	0	0	3	1.00
Latvia	4	151	155	34	0.18
Lebanon	4	10	14	156	0.92
Lesotho	1	3	4	0	0.00
Liberia	1	2	3	8	0.73
Libya	1	1	2	16	0.89
Liechtenstein	77	58	135	17	0.11
Lithuania	2	52	54	22	0.29
Luxembourg	121	402	523	101	0.16
Madagascar	1	4	5	9	0.64
Malawi	2	1	3	0	0.00
Malaysia	40	112	152	395	0.72
Maldives	0	0	0	1	1.00
Mali	0	1	1	1	0.50
Malta	11	7	18	27	0.60
Marshall Islands (the)	0	0	0	0	
Martinique	0	0	0	0	
Mauritania	0	0	0	10	1.00
Mauritius	1	3	4	36	0.90
Mexico	74	520	594	243	0.29
Micronesia (Federated States of)	0	0	0	0	
Monaco	148	10	158	12	0.07
Mongolia	0	1	1	4	0.80
Montenegro	0	0	0	0	
Montserrat	0	0	0	0	
Morocco	2	24	26	198	0.88
Mozambique	0	0	0	0	
Myanmar	0	0	0	14	1.00
Namibia	1	5	6	2	0.25
Nauru	0	0	0	1	1.00
Nepal	0	0	0	18	1.00
Netherlands (the)	1,325	15,666	16,991	1,986	0.10
New Caledonia	0	0	0	0	
New Zealand	452	2,618	3,070	584	0.16
Nicaragua	0	0	0	2	1.00
Niger (the)	0	0	0	10	1.00
Nigeria	1	2	3	106	0.97
Niue	0	0	0	0	
Norfolk Island	0	0	0	0	
Northern Mariana Islands	0	0	0	0	
Norway	339	6,500	6,839	419	0.06
Oman	1	0	1	0	0.00
Pakistan	0	6	6	116	0.95
Palau	0	0	0	0	
Palestine	0	0	0	0	
Panama	10	1	11	12	0.52
Papua New Guinea	2	1	3	0	0.00
Paraguay	0	0	0	1	1.00
Peru	4	11	15	31	0.67

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Philippines (the)	39	115	154	135	0.47
Pitcairn	0	0	0	0	
Poland	20	997	1,017	536	0.35
Portugal	31	228	259	169	0.39
Puerto Rico	0	0	0	0	
Qatar	3	1	4	1	0.20
Republic of Korea (the)	68	11,391	11,459	763	0.06
Republic of Moldova (the)	2	39	41	14	0.25
Réunion	0	0	0	0	
Romania	1	227	228	194	0.46
Russian Federation (the)	43	11,930	11,973	1,662	0.12
Rwanda	0	0	0	5	1.00
Saint Barthélemy	0	0	0	0	
Saint Helena	0	0	0	0	
Saint Kitts and Nevis	0	0	0	5	1.00
Saint Lucia	0	0	0	2	1.00
Saint Martin (French part)	0	0	0	0	
Saint Pierre and Miquelon	0	0	0	0	
Saint Vincent and the Grenadines	1	0	1	0	0.00
Samoa	0	0	0	0	
San Marino	0	1	1	2	0.67
Sao Tome and Principe	0	0	0	0	
Saudi Arabia	68	21	89	19	0.18
Senegal	1	0	1	8	0.89
Serbia	0	0	0	0	
Seychelles	0	0	0	2	1.00
Sierra Leone	0	0	0	7	1.00
Singapore	668	843	1,511	136	0.08
Sint Maarten (Dutch part)	0	0	0	0	
Slovakia	7	314	321	100	0.24
Slovenia	5	574	579	82	0.12
Solomon Islands	0	0	0	0	
Somalia	0	0	0	0	
South Africa	358	2,360	2,718	235	0.08
South Sudan	0	0	0	0	
Soviet Union	0	564	564	2	0.00
Spain	414	6,539	6,953	927	0.12
Sri Lanka	5	26	31	158	0.84
Sudan (the)	0	12	12	31	0.72
Suriname	0	0	0	1	1.00
Svalbard and Jan Mayen	0	0	0	0	
Swaziland	0	0	0	4	1.00
Sweden	1,340	27,700	29,040	1,160	0.04
Switzerland	4,544	11,428	15,972	951	0.06
Syrian Arab Republic	0	8	8	36	0.82
Tajikistan	1	0	1	1	0.50
Thailand	30	66	96	64	0.40
the former Yugoslav Republic of Macedonia	0	24	24	19	0.44
Timor-Leste	0	0	0	0	
Togo	0	2	2	12	0.86
Tonga	0	0	0	0	
Trinidad and Tobago	1	6	7	19	0.73
Tunisia	1	20	21	156	0.88

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Turkey	13	470	483	400	0.45
Turkmenistan	0	0	0	0	
Turks and Caicos Islands	0	0	0	0	
Tuvalu	0	0	0	0	
Uganda	0	4	4	13	0.76
Ukraine	14	913	927	275	0.23
United Arab Emirates (the)	22	8	30	2	0.06
United Kingdom of Great Britain and Northern Ireland (the)	5,248	67,918	73,166	8,930	0.11
United Republic of Tanzania (the)	1	0	1	11	0.92
United States of America (the)	31,358	163,725	195,083	3,205	0.02
United States Virgin Islands	0	0	0	0	
Uruguay	7	21	28	30	0.52
Uzbekistan	4	56	60	6	0.09
Vanuatu	0	0	0	0	
Venezuela (Bolivarian Republic of)	8	39	47	62	0.57
Viet Nam	1	9	10	61	0.86
Wallis and Futuna Islands	0	0	0	0	
Western Sahara	0	0	0	0	
Yemen	0	2	2	2	0.50
Yugoslavia (Serbia and Montenegro)	2	140	142	278	0.66
Zambia	2	0	2	3	0.60
Zimbabwe	4	10	14	21	0.60

Notes: This study uses the list of countries, areas or territories used by the United Nations Statistics Division. See http://unstats.un.org/unsd/methods/m49/m49alpha.htm (accessed 24th August 2013). "Yugoslavia (Serbia and Montenegro)" only includes Serbia and Montenegro and data are only available up to 2005. Data for Serbia and for Montenegro separately are available from 2006. Data for Czechoslovakia are only available up to 1991, while data for Slovakia and for the Czech Republic become available in 1992. Data for Eritrea only become available in 1993. Data for South Sudan, Curacao, Sint Maarten, and Bonaire are not included. Data for Saint Barthélemy and Saint Martin are only available from 2007. Data for Guernsey and Jersey are only available from 2004. Data for Aland Islands are available only from 2003. Data for the Palestine are available only from 1999. Data for the Soviet Union are only available up to 1991. Data for the former Soviet Republics become available in 1991.

Table A3: Immigrants, emigrants and emigration rates, 2001-2010

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Afghanistan	0	0	0	13	1.00
Åland Islands	0	0	0	0	
Albania	0	10	10	107	0.91
Algeria	6	78	84	488	0.85
American Samoa	0	0	0	0	
Andorra	29	3	32	10	0.24
Angola	3	0	3	3	0.50
Anguilla	0	0	0	0	
Antigua and Barbuda	11	0	11	11	0.50
Argentina	100	1,119	1,219	1,259	0.51
Armenia	3	115	118	170	0.59
Aruba	0	0	0	0	
Australia	4,427	35,088	39,515	5,631	0.12
Austria	3,113	21,896	25,009	5,122	0.17
Azerbaijan	12	76	88	64	0.42
Bahamas (the)	117	9	126	19	0.13
Bahrain	12	8	20	4	0.17
Bangladesh	2	18	20	637	0.97
Barbados	25	7	32	17	0.35
Belarus	7	436	443	479	0.52
Belgium	5,042	22,122	27,164	3,567	0.12
Belize	4	2	6	26	0.81
Benin	0	6	6	19	0.76
Bermuda	0	0	0	0	
Bhutan	0	3	3	0	0.00
Bolivia (Plurinational State of)	6	14	20	78	0.80
Bonaire, Sint Eustatius and Saba	0	0	0	0	
Bosnia and Herzegovina	2	97	99	266	0.73
Botswana	2	1	3	1	0.25
Brazil	376	9,050	9,426	1,859	0.16
British Virgin Islands	0	0	0	0	
Brunei Darussalam	8	2	10	7	0.41
Bulgaria	9	617	626	1,288	0.67
Burkina Faso	0	15	15	8	0.35
Burundi	5	4	9	7	0.44
Cambodia	1	0	1	17	0.94
Cameroon	3	28	31	169	0.85
Canada	7,257	58,551	65,808	21,315	0.24
Cape Verde	0	1	1	0	0.00
Cayman Islands	0	0	0	0	
Central African Republic (the)	0	1	1	2	0.67
Chad	0	1	1	3	0.75
Chile	115	855	970	383	0.28
China	4,251	137,651	141,902	53,610	0.27
China, Hong Kong SAR	5	12	17	1	0.06
China, Macao SAR	0	0	0	0	
Colombia	35	675	710	847	0.54
Comoros (the)	1	0	1	4	0.80
Congo (the)	0	4	4	38	0.90
Cook Islands (the)	0	0	0	0	
Costa Rica	33	108	141	138	0.49
Côte d'Ivoire	5	5	10	33	0.77
Croatia	23	1,418	1,441	617	0.30
Cuba	1	996	997	206	0.17
Curaçao	0	0	0	0	

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Cyprus	52	77	129	349	0.73
Czech Republic	116	3,574	3,690	935	0.20
Czechoslovakia	0	0	0	0	
Democratic People's Republic of Korea (the)	1	45	46	124	0.73
Democratic Republic of the Congo (the)	2	2	4	29	0.88
Denmark	2,589	23,364	25,953	2,411	0.09
Djibouti	0	0	0	0	
Dominica	0	2	2	27	0.93
Dominican Republic (the)	3	32	35	42	0.55
Ecuador	12	52	64	150	0.70
Egypt	41	533	574	913	0.61
El Salvador	0	9	9	41	0.82
Equatorial Guinea	0	1	1	3	0.75
Eritrea	0	0	0	38	1.00
Estonia	34	802	836	192	0.19
Ethiopia	0	3	3	228	0.99
Faeroe Islands	0	0	0	0	
Falkland Islands (Malvinas)	0	0	0	0	
Fiji	3	2	5	7	0.58
Finland	3,095	32,314	35,409	1,675	0.05
France	9,540	141,413	150,953	19,123	0.11
French Guiana	0	0	0	0	
French Polynesia	0	0	0	0	
Gabon	5	4	9	16	0.64
Gambia (the)	2	0	2	0	0.00
Georgia	5	168	173	102	0.37
Germany	25,341	432,136	457,477	32,158	0.07
Ghana	5	15	20	152	0.88
Gibraltar	0	0	0	0	
Greece	74	1,951	2,025	3,209	0.61
Greenland	0	0	0	0	
Grenada	2	0	2	3	0.60
Guadeloupe	0	0	0	0	
Guam	0	0	0	0	
Guatemala	1	22	23	94	0.80
Guernsey	0	0	0	0	
Guinea	1	0	1	8	0.89
Guinea-Bissau	0	0	0	3	1.00
Guyana	2	0	2	62	0.97
Haiti	1	1	2	26	0.93
Holy See (the)	0	0	0	1	1.00
Honduras	1	1	2	26	0.93
Hungary	102	6,702	6,804	1,324	0.16
Iceland	72	697	769	392	0.34
India	532	37,954	38,486	40,097	0.51
Indonesia	64	206	270	1,040	0.79
Iran (Islamic Republic of)	4	97	101	2,253	0.96
Iraq	0	10	10	167	0.94
Ireland	1,689	6,803	8,492	2,686	0.24
Isle of Man	0	0	0	0	
Israel	694	41,307	42,001	3,668	0.08
Italy	2,060	60,913	62,973	9,820	0.13
Jamaica	8	17	25	148	0.86
Japan	6,715	578,101	584,816	6,986	0.01
Jersey	0	0	0	0	

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Jordan	38	108	146	420	0.74
Kazakhstan	6	293	299	54	0.15
Kenya	32	54	86	182	0.68
Kiribati	0	0	0	2	1.00
Kuwait	16	13	29	8	0.22
Kyrgyzstan	1	14	15	16	0.52
Lao People's Democratic Republic (the)	1	1	2	54	0.96
Latvia	32	590	622	74	0.11
Lebanon	25	75	100	708	0.88
Lesotho	0	0	0	0	
Liberia	1	0	1	13	0.93
Libya	1	7	8	29	0.78
Liechtenstein	135	129	264	63	0.19
Lithuania	8	303	311	182	0.37
Luxembourg	322	587	909	284	0.24
Madagascar	3	19	22	26	0.54
Malawi	0	1	1	9	0.90
Malaysia	524	3,630	4,154	2,682	0.39
Maldives	0	0	0	0	
Mali	0	1	1	8	0.89
Malta	32	55	87	63	0.42
Marshall Islands (the)	0	0	0	0	
Martinique	0	0	0	0	
Mauritania	0	0	0	33	1.00
Mauritius	1	5	6	150	0.96
Mexico	164	3,659	3,823	1,794	0.32
Micronesia (Federated States of)	0	0	0	0	
Monaco	225	20	245	3	0.01
Mongolia	18	12	30	35	0.54
Montenegro	2	2	4	11	0.73
Montserrat	0	0	0	0	
Morocco	14	213	227	617	0.73
Mozambique	0	0	0	3	1.00
Myanmar	0	3	3	91	0.97
Namibia	8	15	23	10	0.30
Nauru	0	0	0	5	1.00
Nepal	0	5	5	260	0.98
Netherlands (the)	9,665	60,513	70,178	9,132	0.12
New Caledonia	0	0	0	0	
New Zealand	1,249	6,277	7,526	1,839	0.20
Nicaragua	0	0	0	39	1.00
Niger (the)	1	0	1	37	0.97
Nigeria	8	10	18	345	0.95
Niue	0	0	0	0	
Norfolk Island	0	0	0	0	
Northern Mariana Islands	0	0	0	0	
Norway	1,245	12,327	13,572	1,106	0.08
Oman	24	4	28	10	0.26
Pakistan	3	78	81	969	0.92
Palau	0	0	0	0	
Palestine	0	0	0	0	
Panama	14	17	31	43	0.58
Papua New Guinea	1	0	1	6	0.86
Paraguay	3	15	18	15	0.45
Peru	8	67	75	318	0.81
Philippines (the)	108	565	673	704	0.51

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Pitcairn	0	0	0	0	
Poland	71	4,488	4,559	2,537	0.36
Portugal	242	2,149	2,391	1,133	0.32
Puerto Rico	0	0	0	0	
Qatar	42	1	43	4	0.09
Republic of Korea (the)	1,472	162,606	164,078	9,127	0.05
Republic of Moldova (the)	5	75	80	112	0.58
Réunion	0	0	0	0	
Romania	22	749	771	2,589	0.77
Russian Federation (the)	223	20,338	20,561	7,878	0.28
Rwanda	0	0	0	15	1.00
Saint Barthélemy	0	0	0	0	
Saint Helena	0	0	0	0	
Saint Kitts and Nevis	0	1	1	5	0.83
Saint Lucia	0	1	1	5	0.83
Saint Martin (French part)	0	0	0	0	
Saint Pierre and Miquelon	0	0	0	0	
Saint Vincent and the Grenadines	0	0	0	5	1.00
Samoa	0	0	0	3	1.00
San Marino	5	16	21	3	0.13
Sao Tome and Principe	0	0	0	2	1.00
Saudi Arabia	569	524	1,093	70	0.06
Senegal	4	8	12	67	0.85
Serbia	1	254	255	680	0.73
Seychelles	9	1	10	5	0.33
Sierra Leone	0	8	8	22	0.73
Singapore	6,720	6,311	13,031	1,166	0.08
Sint Maarten (Dutch part)	0	0	0	0	
Slovakia	26	878	904	582	0.39
Slovenia	15	2,980	2,995	182	0.06
Solomon Islands	0	0	0	0	
Somalia	0	2	2	8	0.80
South Africa	426	6,355	6,781	1,281	0.16
South Sudan	0	0	0	0	
Soviet Union	0	0	0	0	
Spain	2,406	33,380	35,786	5,154	0.13
Sri Lanka	9	123	132	747	0.85
Sudan (the)	0	28	28	72	0.72
Suriname	0	2	2	15	0.88
Svalbard and Jan Mayen	0	0	0	0	
Swaziland	0	1	1	13	0.93
Sweden	4,832	52,451	57,283	4,025	0.07
Switzerland	20,416	32,737	53,153	3,005	0.05
Syrian Arab Republic	5	50	55	175	0.76
Tajikistan	5	3	8	3	0.27
Thailand	205	520	725	725	0.50
the former Yugoslav Republic of Macedonia	1	37	38	182	0.83
Timor-Leste	0	0	0	0	
Togo	0	4	4	16	0.80
Tonga	0	0	0	20	1.00
Trinidad and Tobago	9	40	49	122	0.71
Tunisia	11	135	146	597	0.80
Turkey	74	6,128	6,202	3,119	0.33

Country/Territory	Immigrants	Nationals	Residents	Emigrants	Emig. share
Turkmenistan	0	4	4	7	0.64
Turks and Caicos Islands	0	0	0	0	
Tuvalu	0	0	0	0	
Uganda	1	1	2	62	0.97
Ukraine	23	2,441	2,464	1,911	0.44
United Arab Emirates (the)	273	63	336	13	0.04
United Kingdom of Great Britain and Northern Ireland (the)	15,758	119,824	135,582	27,746	0.17
United Republic of Tanzania (the)	5	2	7	74	0.91
United States of America (the)	194,609	875,962	1,070,571	11,131	0.01
United States Virgin Islands	0	0	0	0	
Uruguay	25	106	131	163	0.55
Uzbekistan	0	46	46	100	0.68
Vanuatu	1	0	1	3	0.75
Venezuela (Bolivarian Republic of)	32	77	109	589	0.84
Viet Nam	20	107	127	773	0.86
Wallis and Futuna Islands	0	0	0	0	
Western Sahara	0	0	0	0	
Yemen	0	1	1	26	0.96
Yugoslavia (Serbia and Montenegro)	0	242	242	533	0.69
Zambia	0	4	4	28	0.88
Zimbabwe	4	15	19	80	0.81

Notes: This study uses the list of countries, areas or territories used by the United Nations Statistics Division. See http://unstats.un.org/unsd/methods/m49/m49alpha.htm (accessed 24th August 2013). "Yugoslavia (Serbia and Montenegro)" only includes Serbia and Montenegro and data are only available up to 2005. Data for Serbia and for Montenegro separately are available from 2006. Data for Czechoslovakia are only available up to 1991, while data for Slovakia and for the Czech Republic become available in 1992. Data for Eritrea only become available in 1993. Data for South Sudan, Curacao, Sint Maarten, and Bonaire are not included. Data for Saint Barthélemy and Saint Martin are only available from 2007. Data for Guernsey and Jersey are only available from 2004. Data for Aland Islands are available only from 2003. Data for Palestine are available only from 1999. Data for the Soviet Union are only available up to 1991. Data for the former Soviet Republics become available in 1991.

Appendix 4: Largest inventor migration corridors from and between non-high income countries

Table A4: Migration corridors from non-high income countries, 1991-2000

Largest inventor migration corridors coming from non-high income countries			Largest inventor migration corridors coming from non-high income countries, without US		
Origin	Destination	Counts	Origin	Destination	Counts
China	US	6,279	China	Japan	402
India	US	4,470	China	UK	328
Russia	US	842	China	Germany	311
China	Japan	402	Iran	Germany	204
China	UK	328	China	Canada	203
China	Germany	311	Russia	Germany	187
Iran	US	233	China	Singapore	181
Argentina	US	209	China	Australia	135
Iran	Germany	204	India	Japan	123
China	Canada	203	India	UK	121
Russia	Germany	187	Turkey	Germany	118
China	Singapore	181	China	Sweden	111
Turkey	US	178	India	Canada	110
Mexico	US	166	India	Singapore	108
Brazil	US	152	Malaysia	Singapore	100
China	Australia	135	Tunisia	France	94
Bulgaria	US	128	Russia	UK	85
Ukraine	US	126	China	France	82
Yugoslavia (Serbia and Montenegro)	US	125	Morocco	France	68
India	Japan	123	Malaysia	UK	68
India	UK	121	Iran	UK	61
Turkey	Germany	118	Yugoslavia (Serbia and Montenegro)	Germany	60
Malaysia	US	114	Russia	Canada	57
China	Sweden	111	Algeria	France	57
India	Canada	110	Ukraine	Germany	55
India	Singapore	108	Russia	Sweden	54
Malaysia	Singapore	100	Malaysia	Australia	52
Tunisia	France	94	South Africa	UK	52
Chile	US	94	Russia	Switzerland	51
Sri Lanka	US	86	Russia	France	47

Table A5: Migration corridors from non-high income countries, 2001-2010

Largest inventor migration corridors coming from non-high income countries			Largest inventor migration corridors coming from non-high income countries, without US		
Origin	Destination	Counts	Origin	Destination	Counts
China	US	44,452	China	Japan	2,510
India	US	35,621	China	Singapore	1,923
Russia	US	4,339	Russia	Germany	1,207
China	Japan	2,510	Malaysia	Singapore	1,090
China	Singapore	1,923	China	UK	920
Turkey	US	1,922	China	Germany	892
Iran	US	1,438	India	Singapore	847
Romania	US	1,220	China	Canada	652
Russia	Germany	1,207	Turkey	Germany	601
Mexico	US	1,161	India	UK	556
Brazil	US	1,115	India	Germany	542
Malaysia	Singapore	1,090	India	Canada	440
Ukraine	US	977	Ukraine	Germany	416
China	UK	920	China	Sweden	343
China	Germany	892	Russia	UK	337
India	Singapore	847	China	R. of Korea	334
Argentina	US	820	India	Japan	319
Malaysia	US	729	India	Netherlands	319
South Africa	US	719	China	Netherlands	317
Egypt	US	667	China	Finland	281
China	Canada	652	Romania	Germany	264
Pakistan	US	626	Malaysia	UK	259
Bulgaria	US	626	Tunisia	France	257
Turkey	Germany	601	China	Australia	246
India	UK	556	Morocco	France	239
India	Germany	542	Romania	Netherlands	238
Colombia	US	532	Russia	Sweden	231
Thailand	US	494	Bulgaria	Germany	226
Philippines	US	450	Russia	Finland	204
India	Canada	440	Algeria	France	195

Table A6: Migration corridors to non-high income countries, 1991-2000 and 2001-2010

Largest inventor migration corridors from high income to non-high income countries 1991-2000			Largest inventor migration corridors from high income to non-high income countries 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
UK	South Africa	175	US	China	1,295
UK	China	81	Germany	China	468
Germany	Brazil	73	UK	China	401
US	China	62	Canada	China	387
Germany	South Africa	54	US	India	340
Chile	Brazil	32	Australia	China	327
Germany	Mexico	27	France	China	211
Australia	China	25	Japan	China	138
Netherlands	South Africa	25	UK	South Africa	128
Germany	China	21	Singapore	China	117
Canada	China	20	Finland	China	99
Italy	Argentina	17	R. of Korea	China	98
US	Mexico	15	Netherlands	China	88
Italy	Brazil	14	Germany	South Africa	76
Russia	Ukraine	12	Malaysia	China	68
India	Philippines	11	Sweden	China	64
US	India	10	New Zealand	China	58
Singapore	Malaysia	9	Denmark	China	58
Argentina	Brazil	9	India	China	57
UK	Malaysia	9	UK	India	53
Italy	South Africa	9	US	Malaysia	52
Belgium	South Africa	8	India	Malaysia	50
Italy	Panama	8	Indonesia	Malaysia	49
Ukraine	Russia	8	Ukraine	Russia	46
Finland	South Africa	8	Belgium	China	45
US	Thailand	8	Germany	Brazil	44
Greece	South Africa	7	UK	Malaysia	43
Russia	Kazakhstan	7	Germany	Malaysia	43
Germany	Turkey	6	Ireland	China	42
US	Philippines	6	US	Thailand	39

Table A7: Migration corridors among non-high income countries, 1991-2000 and 2001-2010

Largest inventor migration corridors between non-high income countries, 1991-2000			Largest inventor migration corridors between non-high income countries, 2001-2010		
Origin	Destination	Counts	Origin	Destination	Counts
Chile	Brazil	32	Malaysia	China	68
Russia	Ukraine	12	India	China	57
India	Philippines	11	India	Malaysia	50
Argentina	Brazil	9	Indonesia	Malaysia	49
Ukraine	Russia	8	Ukraine	Russia	46
Russia	Kazakhstan	7	Argentina	Brazil	31
Bulgaria	South Africa	6	Philippines	China	27
Romania	South Africa	6	Colombia	Brazil	24
Zimbabwe	South Africa	5	Iraq	Malaysia	22
Philippines	China	4	Iran	Malaysia	20
Armenia	Russia	4	Turkey	South Africa	19
Russia	Uzbekistan	4	Ukraine	Mongolia	18
Argentina	South Africa	4	Nepal	China	18
Russia	Cuba	3	China	Malaysia	17
Russia	Latvia	3	Bangladesh	Malaysia	15
Venezuela	Mexico	3	Chile	Brazil	14
Argentina	Mexico	3	Armenia	Russia	13
Georgia	Russia	3	Zimbabwe	South Africa	13
Malaysia	China	2	Yemen	Malaysia	12
Zimbabwe	Malawi	2	Pakistan	China	12
India	Sri Lanka	2	Argentina	Uruguay	12
Ecuador	Mexico	2	Russia	Latvia	11
India	Mexico	2	Indonesia	China	11
Cuba	El Salvador	2	Venezuela	Colombia	10
Tanzania	Kenya	2	India	Thailand	10
Colombia	Brazil	2	Argentina	Mexico	10
Argentina	Uruguay	2	Pakistan	Malaysia	10
Russia	Moldova	2	Azerbaijan	Turkey	9
Jordan	Egypt	2	Colombia	Chile	9
Yugoslavia (Serbia and Montenegro)	Russia	2	Russia	Azerbaijan	9

Appendix 5: WIPO's technology classification of IPC codes
Table A8: Patent IPC – technology mapping

Technology	Disaggregated technology
Electrical engineering	Electrical machinery, energy
Electrical engineering	Audio-visual technology
Electrical engineering	Telecommunications
Electrical engineering	Digital communication
Electrical engineering	Basic communication processes
Electrical engineering	Computer technology
Electrical engineering	IT methods for management
Electrical engineering	Semiconductors
Instruments	Optics
Instruments	Measurement
Instruments	Analysis of bio materials
Instruments	Control apparatus
Instruments	Medical technology
Chemistry	Organic fine chemistry
Chemistry	Biotechnology
Chemistry	Pharmaceuticals
Chemistry	Macromolecular chemistry, polymers
Chemistry	Food chemistry
Chemistry	Basic materials chemistry
Chemistry	Materials metallurgy
Chemistry	Surface tech coating
Chemistry	Micro-structure and nano-technology
Chemistry	Chemical engineering
Chemistry	Environmental technology
Mechanical engineering	Handling
Mechanical engineering	Machine tools
Mechanical engineering	Engines, pumps, turbines
Mechanical engineering	Textile and paper
Mechanical engineering	Other spec machines
Mechanical engineering	Thermal processes and apparatus
Mechanical engineering	Mechanical elements
Mechanical engineering	Transport
Other	Furniture, games
Other	Other cons goods
Other	Civil engineering
Other	Other

Source:(Schmoch 2008)**.**

Appendix 6: Immigration rates of inventors by 35-group technology
Table A9: Migration rates of inventors across 35 technologies, 2001-2010

Immigration rate of inventors		Immigration rate of inventors from low and middle income economies	
Electrical machinery, energy	7.03	Electrical machinery, energy	3.01
Audio-visual technology	9.05	Audio-visual technology	4.37
Telecommunications	11.98	Telecommunications	6.58
Digital communication	15.53	Digital communication	9.43
Basic communication processes	15.16	Basic communication processes	8.30
Computer technology	13.35	Computer technology	6.93
IT methods for management	9.74	IT methods for management	4.45
Semiconductors	11.78	Semiconductors	6.28
Optics	7.86	Optics	3.53
Measurement	9.43	Measurement	4.12
Analysis of bio materials	13.86	Analysis of bio materials	5.94
Control apparatus	6.79	Control apparatus	2.88
Medical technology	7.85	Medical technology	3.13
Organic fine chemistry	13.85	Organic fine chemistry	5.79
Biotechnology	15.27	Biotechnology	6.64
Pharmaceuticals	14.33	Pharmaceuticals	6.01
Macromolecular chemistry, polymers	9.64	Macromolecular chemistry, polymers	4.13
Food chemistry	10.34	Food chemistry	3.47
Basic materials chemistry	10.57	Basic materials chemistry	3.99
Materials metallurgy	7.33	Materials metallurgy	3.41
Surface tech coating	8.14	Surface tech coating	3.68
Micro-structure and nano-technology	17.20	Micro-structure and nano-technology	10.81
Chemical engineering	8.59	Chemical engineering	3.66
Environmental technology	6.67	Environmental technology	2.86
Handling	4.81	Handling	1.18
Machine tools	4.54	Machine tools	1.62
Engines, pumps, turbines	6.03	Engines, pumps, turbines	1.85
Textile and paper	6.36	Textile and paper	2.19
Other spec machines	6.29	Other spec machines	2.24
Thermal processes and apparatus	5.41	Thermal processes and apparatus	2.02
Mechanical elements	4.07	Mechanical elements	1.11
Transport	4.24	Transport	1.01
Furniture, games	4.92	Furniture, games	1.12
Other cons goods	5.38	Other cons goods	1.48
Civil engineering	6.82	Civil engineering	2.21
Other	7.03	Other	3.01

Appendix 7: Most populated corridors, by technology

Table A10: Largest inventor migration corridors, Electrical engineering, 2001-2010

Largest inventor migration corridors			Largest inventor migration corridors without US		
Origin	Destination	Counts	Origin	Destination	Counts
India	US	21,892	Germany	Switzerland	1,501
China	US	18,605	Germany	Netherlands	1,229
Canada	US	7,604	China	Japan	1,228
UK	US	4,708	China	Singapore	1,219
R. of Korea	US	4,025	Austria	Germany	942
Germany	US	3,203	France	Germany	738
France	US	2,403	Malaysia	Singapore	721
Japan	US	1,867	Netherlands	Germany	649
Israel	US	1,749	UK	Netherlands	555
Germany	Switzerland	1,501	R. of Korea	Japan	542
Russia	US	1,423	US	China	537
Australia	US	1,314	Italy	Germany	531
Germany	Netherlands	1,229	France	UK	495
China	Japan	1,228	Germany	UK	489
China	Singapore	1,219	India	Singapore	483
Italy	US	1,209	Germany	Austria	459
Netherlands	US	1,157	Germany	France	449
Turkey	US	1,149	US	Germany	444
Austria	Germany	942	China	Germany	422
Iran	US	853	Italy	Netherlands	418
France	Germany	738	US	Canada	417
Malaysia	Singapore	721	Italy	UK	396
Spain	US	693	China	UK	394
Greece	US	656	Germany	Sweden	393
Sweden	US	652	France	Switzerland	346
Netherlands	Germany	649	US	UK	333
Romania	US	581	Netherlands	France	322
UK	Netherlands	555	Russia	Germany	315
R. of Korea	Japan	542	Spain	Germany	315
US	China	537	France	Netherlands	299

Table A11: Largest inventor migration corridors, Instruments, 2001-2010

Largest inventor migration corridors			Largest inventor migration corridors without US		
Origin	Destination	Counts	Origin	Destination	Counts
China	US	7,700	Germany	Switzerland	1,730
India	US	5,012	Germany	Netherlands	716
Canada	US	3,477	China	Japan	569
UK	US	2,822	China	Singapore	525
Germany	US	2,337	France	Switzerland	488
Germany	Switzerland	1,730	Netherlands	Germany	446
R. of Korea	US	1,297	Austria	Germany	442
France	US	1,246	Germany	UK	416
Russia	US	1,234	US	Canada	391
Japan	US	998	UK	Netherlands	375
Israel	US	758	Russia	Germany	349
Germany	Netherlands	716	France	UK	316
Australia	US	661	Malaysia	Singapore	287
Netherlands	US	651	France	Germany	270
China	Japan	569	Germany	Austria	267
China	Singapore	525	UK	Germany	265
France	Switzerland	488	UK	Australia	265
Netherlands	Germany	446	Sweden	Switzerland	246
Austria	Germany	442	R. of Korea	Japan	238
Italy	US	429	Italy	Switzerland	236
Turkey	US	429	China	UK	219
Germany	UK	416	US	UK	212
US	Canada	391	Italy	Germany	203
UK	Netherlands	375	US	Germany	203
Switzerland	US	358	Germany	France	196
Russia	Germany	349	Italy	UK	192
Romania	US	322	China	Canada	188
France	UK	316	UK	France	184
Iran	US	315	Netherlands	France	183
Malaysia	Singapore	287	Ireland	UK	181

Table A12: Largest inventor migration corridors, Chemistry, 2001-2010

Largest inventor migration corridors			Largest inventor migration corridors without US		
Origin	Destination	Counts	Origin	Destination	Counts
China	US	33,039	Germany	Switzerland	6,170
India	US	16,383	France	Switzerland	2,253
Canada	US	11,959	UK	Germany	2,000
UK	US	10,820	France	Germany	1,940
Germany	US	6,728	UK	Switzerland	1,708
Germany	Switzerland	6,170	France	UK	1,675
France	US	4,276	China	Japan	1,672
R. of Korea	US	3,880	Netherlands	Germany	1,508
Japan	US	3,485	France	Belgium	1,458
Russia	US	2,984	Austria	Germany	1,345
France	Switzerland	2,253	Germany	Austria	1,293
UK	Germany	2,000	Italy	Switzerland	1,244
France	Germany	1,940	US	Canada	1,142
Australia	US	1,811	Germany	France	1,127
UK	Switzerland	1,708	Germany	UK	1,123
France	UK	1,675	China	Singapore	1,108
China	Japan	1,672	Spain	Germany	1,036
Netherlands	Germany	1,508	US	Germany	1,001
Netherlands	US	1,500	Italy	UK	923
France	Belgium	1,458	Greece	Germany	895
Italy	US	1,445	US	China	877
Austria	Germany	1,345	UK	France	869
Germany	Austria	1,293	Italy	Germany	867
Italy	Switzerland	1,244	Germany	Netherlands	823
US	Canada	1,142	Netherlands	Belgium	792
Germany	France	1,127	UK	Netherlands	762
Germany	UK	1,123	Russia	Germany	751
China	Singapore	1,108	Germany	Belgium	681
Spain	US	1,097	R. of Korea	Japan	680
Spain	Germany	1,036	US	UK	633

Table A13: Largest inventor migration corridors, Mechanical engineering, 2001-2010

Largest inventor migration corridors			Largest inventor migration corridors without US		
Origin	Destination	Counts	Origin	Destination	Counts
China	US	2,297	Germany	Switzerland	1,683
India	US	2,220	Austria	Germany	773
Germany	Switzerland	1,683	France	Germany	615
Canada	US	1,620	China	Japan	441
UK	US	1,516	France	Switzerland	396
Germany	US	1,354	Italy	Germany	390
Austria	Germany	773	Italy	Switzerland	389
France	US	624	Netherlands	Germany	375
France	Germany	615	UK	Germany	370
Japan	US	486	Germany	Austria	364
R. of Korea	US	475	Germany	France	363
China	Japan	441	France	Belgium	268
France	Switzerland	396	Spain	Germany	265
Italy	Germany	390	Germany	UK	255
Italy	Switzerland	389	US	Germany	248
Netherlands	Germany	375	UK	Switzerland	240
UK	Germany	370	UK	France	236
Germany	Austria	364	Turkey	Germany	222
Germany	France	363	Russia	Germany	212
Australia	US	339	France	UK	211
France	Belgium	268	Austria	Switzerland	197
Spain	Germany	265	R. of Korea	Japan	184
Germany	UK	255	China	Singapore	182
Russia	US	254	Greece	Germany	179
Netherlands	US	249	UK	Australia	177
US	Germany	248	Germany	Netherlands	173
UK	Switzerland	240	Germany	Sweden	163
UK	France	236	Malaysia	Singapore	159
Turkey	Germany	222	Netherlands	Belgium	158
Russia	Germany	212	UK	Netherlands	156

Appendix 8: List of countries/territories and classifications

Table A14: Countries/territories and classifications

Country/Territory	Region	OECD	Income group	Population
Afghanistan	Asia	no	Low income	Large
Åland Islands	Europe	no		
Albania	Europe	no	Upper middle	Lower-Middle
Algeria	Africa	no	Upper middle	Large
American Samoa	Oceania & Pacific	no	Upper middle	
Andorra	Europe	no	High income	Small
Angola	Africa	no	Lower middle	Lower-Middle
Anguilla	Latin America & Caribbean	no		
Antigua and Barbuda	Latin America & Caribbean	no	Upper middle	Small
Argentina	Latin America & Caribbean	no	Upper middle	Large
Armenia	Asia	no	Lower middle	Lower-Middle
Aruba	Latin America & Caribbean	no	High income	
Australia	Oceania & Pacific	yes	High income	Upper-Middle
Austria	Europe	yes	High income	Lower-Middle
Azerbaijan	Asia	no	Upper middle	Lower-Middle
Bahamas (the)	Latin America & Caribbean	no	High income	Small
Bahrain	Asia	no	High income	Small
Bangladesh	Asia	no	Low income	Large
Barbados	Latin America & Caribbean	no	High income	Small
Belarus	Europe	no	Upper middle	Lower-Middle
Belgium	Europe	yes	High income	Lower-Middle
Belize	Latin America & Caribbean	no	Lower middle	Small
Benin	Africa	no	Low income	Lower-Middle
Bermuda	North America	no	High income	
Bhutan	Asia	no	Lower middle	Small
Bolivia (Plurinational State of)	Latin America & Caribbean	no	Lower middle	Lower-Middle
Bonaire, Sint Eustatius and Saba	Latin America & Caribbean	no		
Bosnia and Herzegovina	Europe	no	Upper middle	Lower-Middle
Botswana	Africa	no	Upper middle	Small
Brazil	Latin America & Caribbean	no	Upper middle	Large
British Virgin Islands	Latin America & Caribbean	no		
Brunei Darussalam	Asia	no	High income	Small
Bulgaria	Europe	no	Upper middle	Lower-Middle
Burkina Faso	Africa	no	Low income	Lower-Middle
Burundi	Africa	no	Low income	Lower-Middle
Cambodia	Asia	no	Low income	Lower-Middle
Cameroon	Africa	no	Lower middle	Upper-Middle
Canada	North America	yes	High income	Large
Cape Verde	Africa	no	Lower middle	Small
Cayman Islands	Latin America & Caribbean	no	High income	
Central African Republic (the)	Africa	no	Low income	Lower-Middle
Chad	Africa	no	Low income	Lower-Middle
Chile	Latin America & Caribbean	yes	Upper middle	Upper-Middle
China	Asia	no	Upper middle	Large
China, Hong Kong SAR	Asia	no	High income	Lower-Middle
China, Macao SAR	Asia	no	High income	Small
Colombia	Latin America & Caribbean	no	Upper middle	Large
Comoros (the)	Africa	no	Low income	Small
Congo (the)	Africa	no	Lower middle	Lower-Middle
Cook Islands (the)	Oceania & Pacific	no		
Costa Rica	Latin America & Caribbean	no	Upper middle	Lower-Middle
Côte d'Ivoire	Africa	no	Lower middle	Upper-Middle
Croatia	Europe	no	High income	Lower-Middle
Cuba	Latin America & Caribbean	no	Upper middle	Lower-Middle

Country/Territory	Region	OECD	Income group	Population
Curaçao	Latin America & Caribbean	no	High income	
Cyprus	Europe	no	High income	Small
Czech Republic	Europe	yes	High income	Lower-Middle
Czechoslovakia	Europe	no		
Democratic People's Republic of Korea (the)	Asia	no	Low income	Upper-Middle
Democratic Republic of the Congo (the)	Africa	no	Low income	
Denmark	Europe	yes	High income	Lower-Middle
Djibouti	Africa	no	Lower middle	Small
Dominica	Latin America & Caribbean	no	Upper middle	Small
Dominican Republic (the)	Latin America & Caribbean	no	Upper middle	Lower-Middle
Ecuador	Latin America & Caribbean	no	Upper middle	Lower-Middle
Egypt	Africa	no	Lower middle	Large
El Salvador	Latin America & Caribbean	no	Lower middle	Lower-Middle
Equatorial Guinea	Africa	no	High income	Small
Eritrea	Africa	no	Low income	Lower-Middle
Estonia	Europe	yes	High income	Small
Ethiopia	Africa	no	Low income	Large
Faeroe Islands	Europe	no	High income	
Falkland Islands (Malvinas)	Latin America & Caribbean	no		
Fiji	Oceania & Pacific	no	Lower middle	Small
Finland	Europe	yes	High income	Lower-Middle
France	Europe	yes	High income	Large
French Guiana	Latin America & Caribbean	no		
French Polynesia	Oceania & Pacific	no	High income	
Gabon	Africa	no	Upper middle	Small
Gambia (the)	Africa	no	Low income	Small
Georgia	Asia	no	Lower middle	Lower-Middle
Germany	Europe	yes	High income	Large
Ghana	Africa	no	Lower middle	Upper-Middle
Gibraltar	Europe	no	High income	
Greece	Europe	yes	High income	Lower-Middle
Greenland	Europe	no	High income	
Grenada	Latin America & Caribbean	no	Upper middle	Small
Guadeloupe	Latin America & Caribbean	no		
Guam	Oceania & Pacific	no	High income	
Guatemala	Latin America & Caribbean	no	Lower middle	Lower-Middle
Guernsey	Europe	no		
Guinea	Africa	no	Low income	Lower-Middle
Guinea-Bissau	Africa	no	Low income	Small
Guyana	Latin America & Caribbean	no	Lower middle	Small
Haiti	Latin America & Caribbean	no	Low income	Lower-Middle
Holy See (the)	Europe	no		
Honduras	Latin America & Caribbean	no	Lower middle	Lower-Middle
Hungary	Europe	yes	High income	Lower-Middle
Iceland	Europe	yes	High income	Small
India	Asia	no	Lower middle	Large
Indonesia	Asia	no	Lower middle	Large
Iran (Islamic Republic of)	Asia	no	Upper middle	Large
Iraq	Asia	no	Lower middle	Upper-Middle
Ireland	Europe	yes	High income	Lower-Middle
Isle of Man	Europe	no	High income	
Israel	Asia	yes	High income	Lower-Middle
Italy	Europe	yes	High income	Large
Jamaica	Latin America & Caribbean	no	Upper middle	Lower-Middle
Japan	Asia	yes	High income	Large
Jersey	Europe	no		
Jordan	Asia	no	Upper middle	Lower-Middle

Country/Territory	Region	OECD	Income group	Population
Kazakhstan	Asia	no	Upper middle	Upper-Middle
Kenya	Africa	no	Low income	Large
Kiribati	Oceania & Pacific	no	Lower middle	Small
Kuwait	Asia	no	High income	Small
Kyrgyzstan	Asia	no	Low income	Lower-Middle
Lao People's Democratic Republic (the)	Asia	no	Lower middle	Lower-Middle
Latvia	Europe	no	Upper middle	Small
Lebanon	Asia	no	Upper middle	Lower-Middle
Lesotho	Africa	no	Lower middle	Small
Liberia	Africa	no	Low income	Lower-Middle
Libya	Africa	no	Upper middle	Lower-Middle
Liechtenstein	Europe	no	High income	Small
Lithuania	Europe	no	Upper middle	Lower-Middle
Luxembourg	Europe	yes	High income	Small
Madagascar	Africa	no	Low income	Upper-Middle
Malawi	Africa	no	Low income	Lower-Middle
Malaysia	Asia	no	Upper middle	Upper-Middle
Maldives	Asia	no	Upper middle	Small
Mali	Africa	no	Low income	Lower-Middle
Malta	Europe	no	High income	Small
Marshall Islands (the)	Oceania & Pacific	no	Lower middle	Small
Martinique	Latin America & Caribbean	no		
Mauritania	Africa	no	Lower middle	Lower-Middle
Mauritius	Africa	no	Upper middle	Small
Mexico	Latin America & Caribbean	yes	Upper middle	Large
Micronesia (Federated States of)	Oceania & Pacific	no	Lower middle	Small
Monaco	Europe	no	High income	Small
Mongolia	Asia	no	Lower middle	Small
Montenegro	Europe	no	Upper middle	
Montserrat	Latin America & Caribbean	no		
Morocco	Africa	no	Lower middle	Large
Mozambique	Africa	no	Low income	Upper-Middle
Myanmar	Asia	no	Low income	Large
Namibia	Africa	no	Upper middle	Small
Nauru	Oceania & Pacific	no		
Nepal	Asia	no	Low income	Upper-Middle
Netherlands (the)	Europe	yes	High income	Upper-Middle
New Caledonia	Oceania & Pacific	no	High income	
New Zealand	Oceania & Pacific	yes	High income	Lower-Middle
Nicaragua	Latin America & Caribbean	no	Lower middle	Lower-Middle
Niger (the)	Africa	no	Low income	Lower-Middle
Nigeria	Africa	no	Lower middle	Large
Niue	Oceania & Pacific	no		
Norfolk Island	Oceania & Pacific	no		
Northern Mariana Islands	Oceania & Pacific	no	High income	
Norway	Europe	yes	High income	Lower-Middle
Oman	Asia	no	High income	Small
Pakistan	Asia	no	Lower middle	Large
Palau	Oceania & Pacific	no	Upper middle	Small
Palestine	Asia	no	Lower middle	
Panama	Latin America & Caribbean	no	Upper middle	Lower-Middle
Papua New Guinea	Oceania & Pacific	no	Lower middle	Lower-Middle
Paraguay	Latin America & Caribbean	no	Lower middle	Lower-Middle
Peru	Latin America & Caribbean	no	Upper middle	Large
Philippines (the)	Asia	no	Lower middle	Large
Pitcairn	Oceania & Pacific	no		
Poland	Europe	yes	High income	Large

Country/Territory	Region	OECD	Income group	Population
Portugal	Europe	yes	High income	Lower-Middle
Puerto Rico	Latin America & Caribbean	no	High income	
Qatar	Asia	no	High income	Small
Republic of Korea (the)	Asia	yes	High income	Large
Republic of Moldova (the)	Europe	no	Lower middle	Lower-Middle
Réunion	Africa	no		
Romania	Europe	no	Upper middle	Upper-Middle
Russian Federation (the)	Asia	no	Upper middle	Large
Rwanda	Africa	no	Low income	Lower-Middle
Saint Barthélemy	Latin America & Caribbean	no		
Saint Helena	Africa	no		
Saint Kitts and Nevis	Latin America & Caribbean	no	Upper middle	Small
Saint Lucia	Latin America & Caribbean	no	Upper middle	Small
Saint Martin (French part)	Latin America & Caribbean	no	High income	
Saint Pierre and Miquelon	North America	no		
Saint Vincent and the Grenadines	Latin America & Caribbean	no	Upper middle	Small
Samoa	Oceania & Pacific	no	Lower middle	Small
San Marino	Europe	no	High income	Small
Sao Tome and Principe	Africa	no	Lower middle	Small
Saudi Arabia	Asia	no	High income	Upper-Middle
Senegal	Africa	no	Lower middle	Lower-Middle
Serbia	Europe	no	Upper middle	
Seychelles	Africa	no	Upper middle	Small
Sierra Leone	Africa	no	Low income	Lower-Middle
Singapore	Asia	no	High income	Lower-Middle
Sint Maarten (Dutch part)	Latin America & Caribbean	no	High income	
Slovakia	Europe	yes	High income	Lower-Middle
Slovenia	Europe	yes	High income	Small
Solomon Islands	Oceania & Pacific	no	Lower middle	Small
Somalia	Africa	no	Low income	Lower-Middle
South Africa	Africa	no	Upper middle	Large
South Sudan	Africa	no	Low income	
Soviet Union		no		
Spain	Europe	yes	High income	Large
Sri Lanka	Asia	no		Upper-Middle
Sudan (the)	Africa	no	Lower middle	Large
Suriname	Latin America & Caribbean	no	Upper middle	Small
Svalbard and Jan Mayen	Europe	no		
Swaziland	Africa	no	Lower middle	Small
Sweden	Europe	yes	High income	Lower-Middle
Switzerland	Europe	yes	High income	Lower-Middle
Syrian Arab Republic	Asia	no	Lower middle	Upper-Middle
Tajikistan	Asia	no	Low income	Lower-Middle
Thailand	Asia	no	Upper middle	Large
the former Yugoslav Republic of Macedonia	Europe	no	Upper middle	Small
Timor-Leste	Asia	no	Lower middle	Small
Togo	Africa	no	Low income	Lower-Middle
Tonga	Oceania & Pacific	no	Lower middle	Small
Trinidad and Tobago	Latin America & Caribbean	no	High income	Small
Tunisia	Africa	no	Upper middle	Lower-Middle
Turkey	Asia	no	Upper middle	Large
Turkmenistan	Asia	no	Lower middle	Lower-Middle
Turks and Caicos Islands	Latin America & Caribbean	no	High income	
Tuvalu	Oceania & Pacific	no	Lower middle	Small
Uganda	Africa	no	Low income	Large
Ukraine	Europe	no	Lower middle	Large
United Arab Emirates (the)	Asia	no	High income	Lower-Middle

Country/Territory	Region	OECD	Income group	Population
United Kingdom of Great Britain and Northern Ireland (the)	Europe	yes	High income	Large
United Republic of Tanzania (the)	Africa	no	Low income	Large
United States of America (the)	North America	yes	High income	Large
United States Virgin Islands	Latin America & Caribbean	no	High income	
Uruguay	Latin America & Caribbean	no	Upper middle	Lower-Middle
Uzbekistan	Asia	no	Lower middle	Upper-Middle
Vanuatu	Oceania & Pacific	no	Lower middle	Small
Venezuela (Bolivarian Republic of)	Latin America & Caribbean	no	Upper middle	Upper-Middle
Viet Nam	Asia	no	Lower middle	Large
Wallis and Futuna Islands	Oceania & Pacific	no		
Western Sahara	Africa	no		
Yemen	Asia	no	Lower middle	Upper-Middle
Yugoslavia (Serbia and Montenegro)	Europe	no		
Zambia	Africa	no	Lower middle	Lower-Middle
Zimbabwe	Africa	no	Low income	Lower-Middle

Notes: Income groups according to the World Bank classification of 2012. Population's groups are built as follows: Small (<2.5 mill.); Lower-Middle (>2.5 mill. & <15 mill.); Upper-Middle (>15 mill. & <25 mill.); and Large (>25 mill.). The definition of regions follows the United Nations classifications of regions (http://unstats.un.org/unsd/methods/m49/m49regin.htm). "Yugoslavia (Serbia and Montenegro)" only includes Serbia and Montenegro and data are only available up to 2005. Data for Serbia and for Montenegro separately are available from 2006. Data for Czechoslovakia are only available up to 1991, while data for Slovakia and for the Czech Republic become available in 1992. Data for Eritrea only become available in 1993. Data for South Sudan, Curacao, Sint Marteen, and Bonaire are not included. Data for Saint Barthelemy and Saint Martin are only available from 2007. Data for Guernsey and Jersey are only available from 2004. Data for Aland Islands are available only from 2003. Data for Palestine are available only from 1999. Data for the Soviet Union are only available up to 1991. Data for the former Soviet Republics become available in 1991.

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