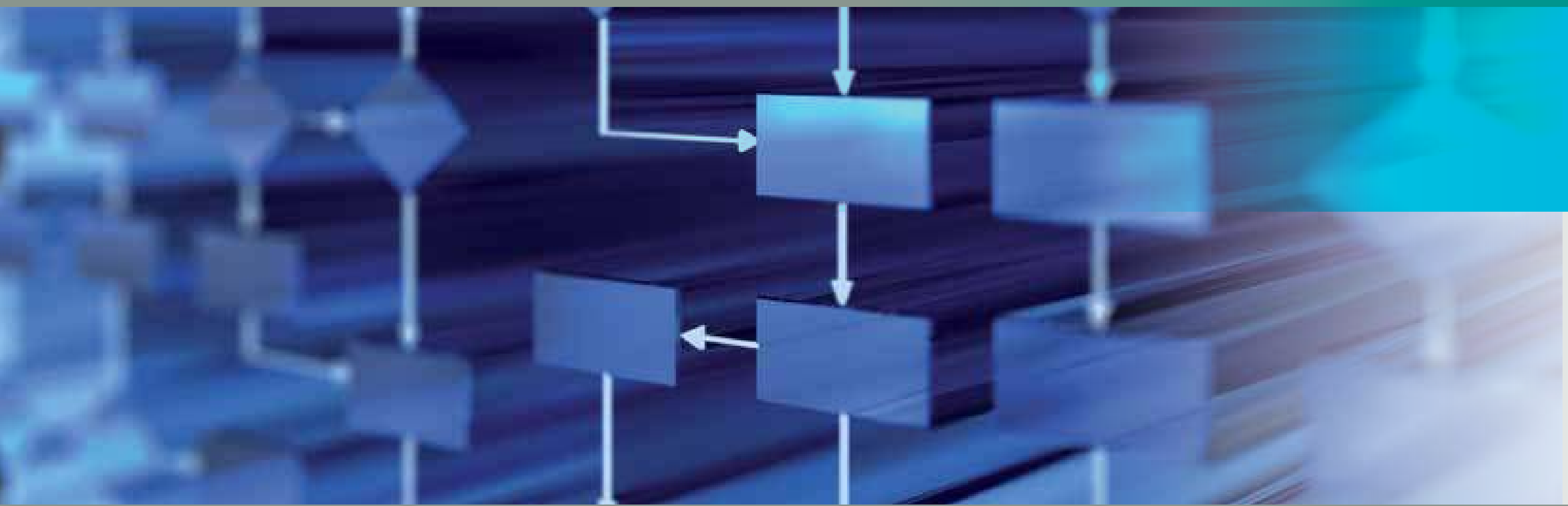

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Measuring the International Mobility of Inventors: A New Database

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Abstract
This paper has two objectives. First, it describes a new database mapping migratory patterns of inventors, extracted from information included in patent applications filed under the Patent Cooperation Treaty. We explain in detail the information contained in the database and discuss the usefulness and reliability of the underlying data. Second, the paper provides a descriptive overview of inventor migration patterns, based on the information contained in the newly constructed database. Among the largest receiving countries, we find that the United States exhibits by far the highest inventor immigration rate, followed by Australia and Canada. European countries lag behind in attracting inventive talent; in addition, France, Germany, and the UK see more inventors emigrating than immigrating. In relation to the number of home country inventors, Central American, Caribbean and African economies show the largest inventor brain drain.

Keywords: brain drain, skilled international migration, inventors, PCT patents

JEL classification: F22, J61, O3, O15

NOTE: All the data used and described in this paper can be downloaded from the WIPO website at http://www.wipo.int/econ_stat/en/economics/publications.html

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1. Introduction

The international mobility of skilled workers and the associated brain drain phenomenon have gained prominence in public policy discussions on innovation and economic growth – in both developed and developing economies. Many governments have made efforts to attract skilled migrants from abroad – inciting what may be colloquially called a global competition for talent.

This paper focuses on a special set of skilled workers, namely inventors, who are arguably at the forefront of technological innovation. In particular, we introduce a new database that maps migratory patterns of inventors, extracted from information contained in patent applications filed under the Patent Cooperation Treaty (PCT). The database contains bilateral counts of "migrant inventors", for a large number of years as well as a considerable number of "sending" and "receiving" countries. In addition to describing this newly constructed database, we provide a descriptive overview of inventor migration patterns around the world.

The importance of high skilled migration is well-recognized in the economic literature. Pioneering contributions to this literature stress the adverse consequences of the loss of nationally trained human capital from developing countries ending up working and living abroad (Bhagwati and Hamada, 1974; Bhagwati and Rodriguez, 1975). In particular, the loss of human capital, tax revenues, innovative competence, absorptive capacity, and positive externalities associated with human capital led authors to emphasize the negative effects of outward migration for development – as encapsulated by the "brain drain" idiom.

Economists adopted a more positive view of skilled worker migration in the 1990s. Several contributions have shown that, under certain circumstances, the emigration of skilled individuals may turn out to be beneficial for the origin country. These contributions have focused on emigrant remittances contributing to origin country GDP growth (Grubel and Scott, 1966; Faini, 2007) and the possibility of realizing a "brain gain" – individuals investing in human capital induced by the prospect of emigrating (Mountford, 1997; Beine et el., 2001). Other beneficial aspects of skilled emigration identified in more recent contributions include return migrants acquiring skills abroad (Rosenzweig, 2008; Mayr and Peri, 2009; Dos Santos and Postel-Vinay, 2004), the emergence of overseas diasporas fostering trade and capital flows (Gould, 1994; Rauch and Trindade, 2002; Docquier and Lodigliani, 2008; Parsons, 2012), diasporas positively influencing home country institutions, values and norms (Li and McHale, 2009; Spilimbergo, 2009), and diasporas inducing further migration flows (Beine et al., 2011; Pedersen et al., 2008). Finally, another recent strand of research has highlighted the role of educated overseas diasporas in transferring knowledge back to their origin countries, with positive effects on home-country innovation and subsequent economic growth (Saxenian, 2002, 2006). However, systematic empirical evidence on the knowledge flows associated with diasporas has only emerged recently, making use of inventor and prior art citation information included in patent applications (Agrawal et al., 2011; Kerr, 2008; Foley and Kerr, 2012) – the same data source we embrace here.

The international mobility of skilled labor has also important implications for receiving countries, typically high income economies. A sizeable literature has sought to quantify the importance of skilled inward migration in those economies as well as its effects on wages (Borjas, 1999, 2003; Ottaviano and Peri, 2006), unemployment (D'Amuri et al., 2008), as well as social cohesion, integration and the perception of immigrants by locals (Mayda, 2006). More recently, economists have analyzed the contribution of immigrants to knowledge creation in their host countries. Hunt and Gauthier-Loiselle (2010), for example, find that a 1 per cent increase in immigrant college graduates is associated with a 9-18 percent rise in patenting. Hunt (2011) reports similar results, while Stephan and Levin (2001) find that the foreign-born contribute disproportionately to science in the United States (US).

Niebuhr (2010) and Partridge and Furtan (2008) present comparable results when investigating how immigrants contribute to innovation in different regions within Germany and Canada, respectively.

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.[3] 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.

Docquier and Marfouk (2006) estimate immigrant stocks in 30 OECD countries for 174 origin countries, for 1990 and 2000. They combine data on the migrant population of age 25 and older, broken down by schooling level, with information on overall human capital stocks published by Barro and Lee (2000), to obtain brain drain rates by education level and country. Defoort (2008) extends this work by providing immigrant stocks by schooling level for five year intervals, from 1975 to 2000, but only to 6 OECD destination countries. 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.[4] 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.[5]

Notwithstanding their value for economic research, census-based datasets have certain limitations.[6] First, some OECD countries – for example, Germany, Italy, Greece, Japan, and Korea – define migrants on a citizenship basis, whereas others employ a country of birth criterion.

Second, 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. Mayda (2010) and Ortega and Peri (2013) provide migration flows to OECD destinations on an annual basis from 1980 to 2005, using the OECD's Continuous Reporting System on Migration data (SOPEMI). However, these data do not take into account the schooling level of migrants.

Third, most existing datasets feature only a limited number of receiving countries.[7] Arguably, the large majority of migration flows, especially skilled migration, involve an OECD country at the receiving end. However, so-called 'South-South' migration has become important for some specific corridors, but it largely escapes measurement. The DIOC-E database enlarges coverage to close to 100 receiving countries, though only using census data from 2000. More recently, Özden et al. (2012) present global matrices of bilateral migrant stocks, spanning 1960-2000, for every 5 years, for 226 receiving and 226 sending countries and territories, by sex and age. Unfortunately, again, these data do not offer a breakdown by schooling level.

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[3] Adams (2003) adopts a similar approach.
[4] Some of these datasets are available at: http://perso.uclouvain.be/frederic.docquier/oxlight.htm (accessed 9th May 2013).
[5] 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 3.0 of this database, see Dumont et al. (2010).
[6] See Docquier and Marfouk (2006) and Hanson (2010).
[7] For example, the studies by Docquier and Marfouk (2006) and Beine et al (2007) only cover around 30 OECD receiving countries.

Fourth, 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, and most important for our purposes, 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. In addition, studies have found migration rates to be higher in certain skill-intensive professions. In particular, the labor force with more than basic tertiary training – for example, PhD holders – tends to be considerably more mobile than the average tertiary educated worker. Recent studies confirm that, indeed, a large share of scientists and technologists trained in developing countries – between 30 and 50 percent – actually live in the developed world (Meyer and Brown, 1999; Barré et al., 2004; cited in Lowell et al., 2004).

Focusing on inventor migration as captured in patent applications can overcome many of the limitations associated with migrant stock 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. As already pointed out, some studies have already looked at migrating inventors and their role as highly-skilled intellectual diasporas (Kerr, 2008; Agrawal et al., 2011; Foley and Kerr, 2012). 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. For example, the migration history of certain ethnicities spans more than one generation – think of 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 – think of Australian or British immigrants in the US.

In this paper, we describe a new dataset on the international mobility of inventors which overcomes many of the data limitations described so far. In particular, we make use of information on both the residence and the nationality of inventors contained in patent applications filed under the Patent Cooperation Treaty (PCT). This approach offers several benefits. First, we directly rely on migratory background information revealed by inventors, rather than indirectly inferring a possible migration history through the cultural origin of names. Second, patent applications filed under the PCT are less influenced by the peculiarities of national patent systems and the underlying inventions are likely to have a larger economic value than the average national patent application. Third, PCT filing data cover a large number of countries and a long time span (from 1978 to 2012). Of course, our database shares some of the drawbacks associated with existing migration databases and relying on patent information has drawbacks on its own, to which we will return.

The rest of the paper is organized as follows. Section 2 describes the PCT system underlying our new database and we outline, in particular, what type of information patent applications record. Section 3 describes the main features of our inventor migration database and Section 4 presents the detailed database structure. In Section 5, we provide a descriptive analysis of inventor migration patterns, as they emerge from our newly constructed database. Section 6 offers concluding remarks.

2. The PCT System as a Source of Inventor Migration Data

Patents and the PCT System

We derive information on the migratory background of inventors from patent applications filed under the PCT. Accordingly, we 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.

A patent is the legal right of an inventor to exclude others from using a particular invention, for a limited number of years. 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 (Griliches, 1979; Hausman et al., 1984), localized knowledge spillovers (Jaffe et al., 1993), international knowledge flows (Peri, 2005), networks of co-inventors (Singh, 2005; Breschi and Lissoni, 2009) and inventor mobility (Almeida and Kogut, 1999; Breschi and Lissoni, 2009).

The PCT is an international treaty administered by the World Intellectual Property Organization (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 146 PCT contracting states in 2012.[8]

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. He 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.[9] Alternatively, the applicant can file an application under the PCT. Choosing the "PCT route" benefits the applicant in two main ways. First, he 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.[10]

Note that under the PCT system, the applicant still has to file applications in all jurisdictions in which he 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.

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[8] For a list of member states, and the date at which the State became bound by the PCT see: http://www.wipo.int/pct/en/pct_contracting_states.html (accessed 9th May 2013).
[9] 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.
[10] 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.

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.[11] Accordingly, applicants have opted for the PCT route for a significant share of international patent applications (see below).

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.[12] 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.

Before turning to how we extracted migratory background information from PCT filing data, we review a number of characteristics of the PCT system that are important to take into account when using these data for economic analysis.

As already mentioned at the outset, not all countries are members of the PCT. Fortunately, the countries that have accounted for the great majority of patent filings over the past three decades – especially China, France, Germany, Japan, the Republic of Korea, the United Kingdom and the US – have either been founding members or joined the system before experiencing rapid patenting growth. Nonetheless, incomplete membership should be taken into account when interpreting data for different filing origins and especially when performing regression analysis.

In 2010, around 54% of all international patent applications went through the PCT system. The PCT share has continuously risen over the past two decades; in 1995 it only stood at 25.4% of all international patents (WIPO, 2012a). In February 2011, the 2 millionth application was filed under the PCT system. However, the system has seen uneven growth since its inception in 1978. In particular, it took 26 years to reach the first million, but only 7 years to reach the second one (WIPO, 2012a). Over the 1978-2011 period, the US accounted for most filings (35.1% of all applications), followed by Japan (15.1%), Germany (11.9%), the United Kingdom (UK) (4.5%), France (4.4%), the Republic of Korea (3.2%) and China (2.9%).

Note that the total number of patent applications filed worldwide – at 2.14 million in 2011 – is considerably larger than the number of PCT filings – at 181,900 in the same year.[13]

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[11] See van Zeebroeck et al., 2009, cited in van Zeebroeck and van Pottelsberghe de la Potterie, 2011.

[12] 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).

[13] WIPO (2012b).

Two considerations account for this difference. First, for the majority of patents – around two-thirds in 2011 – applicants only seek domestic protection and do not apply for protection abroad. Second, each PCT filing may result in several national patent filings, depending on the number of jurisdictions in which the applicant seeks protection.

While the PCT thus captures a sizeable and important share of patent activity worldwide, there are considerable differences in how residents of different countries use the system. First, the propensity of patent applicants to seek protection beyond their national jurisdiction differs markedly. For instance, in 2011, residents of China filed fewer than 20,000 applications outside of China, or only 4.54% of all the applications by Chinese residents worldwide. In contrast, this share is considerably higher for the Republic of Korea (26.4%), Japan (39.1%), US (42.7%), Germany (57.6%), the UK (59.7%), France (62.8%), the Netherlands (74.7%), and Switzerland (78.6%).[14]

Countries also differ in the extent to which they rely on the PCT system – rather than the direct "Paris" route – for their international filings. Recall that, in 2010, the PCT share of international filings for the world stood at around 54%. However, we see substantial variation around this average: the PCT share was between two-thirds and three-quarters for Finland, France, the Netherlands, Sweden, and the US; it was between one-half and two-thirds for Australia, Germany, the Russian Federation, Switzerland and the UK; and it was between one-quarter and one-half for Canada, China, Japan, and the Republic of Korea.

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) (generally, 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 inventor. 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.

In principle, the PCT system only records residence and nationality information for applicants and not inventors. However, it turns out that US patent application procedures, until recently, 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 their residence and nationality information are, in principle, available. Indeed, this is the case for the majority of PCT applications, reflecting the popularity of the US as the world's largest market. In addition – and fortunately for our purposes – a change to PCT rules in 2004 provided that all PCT applications automatically include all PCT member states as designated states, including the US.

Unfortunately – for our purposes – 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.

[14] The higher share of European countries partly reflects the availability of an alternative regional filing route administered by the European Patent Office.

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.[15]

In a nutshell, this means that we have 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.

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 our interest in studying the migratory background of inventors, we focus our attention only on inventor and applicant-inventor records. This subgroup accounts for exactly 6,112,608 records.

Ideally, we 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 literature has disambiguated individual inventors through their names and surnames, as well as other information contained in patent documents.[16] However, these approaches are far from perfect (see Raffo and Lhuillery, 2009). We decided to not engage in any name disambiguation at this point. The raw records on inventors and applicant-inventors already enable meaningful analysis at the aggregate level. In particular, we 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 to our database, though the best disambiguation approach may partly depend on the research question at hand. Indeed, we encourage other researchers to apply their own disambiguation methods to our database. In what follows, our unit of analysis will be the "inventor/applicant-inventor name – patent number" pair.

We observe both nationality and residence information 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, we observe 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.[17]

[15] 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.

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

[17] 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, Hong Kong, and Faroe Islands are linked to

Of the 1,184,532 records that do not offer complete nationality and residence information, 970,336 records – or 81.9% – relate to inventors that are not applicants; the remaining 214,196 records – or 18.1% – 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 we observe this information for the majority of records throughout the PCT system's history. However, the coverage varies over time, standing between 60% and 67% during the 1990s, and between 70 and 92% during the 2000s. It increases markedly after 2004, reflecting the PCT rule change described above. Unfortunately, we 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.[18] 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

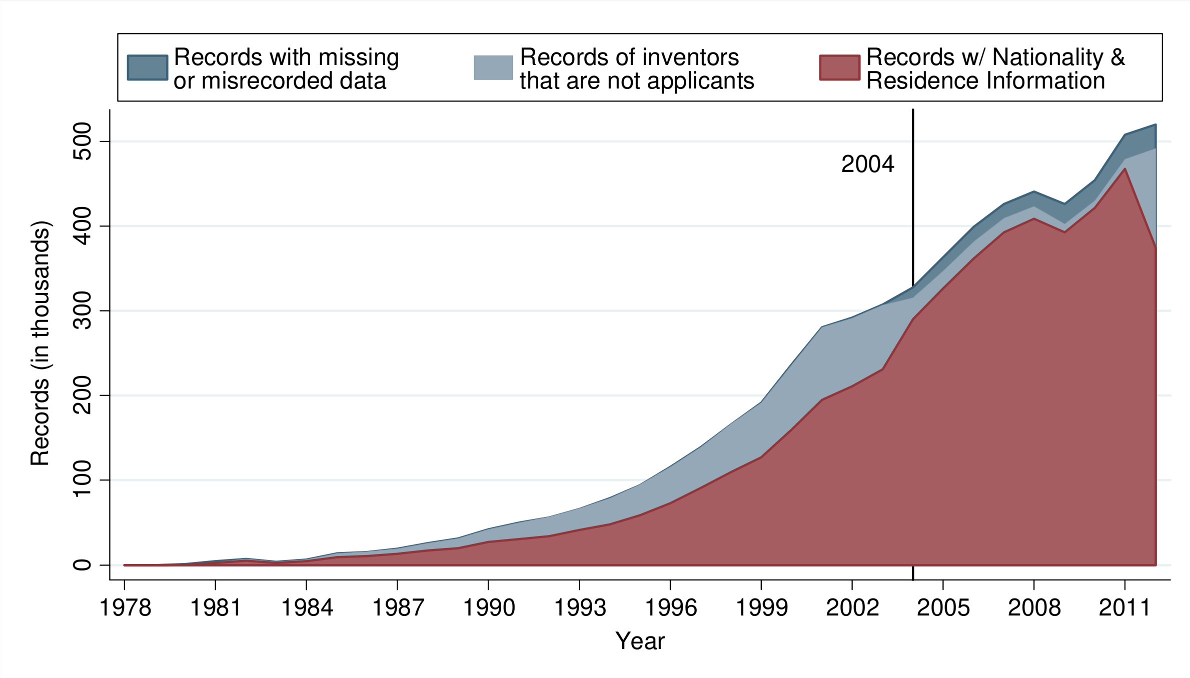


Table 1 shows how the coverage of nationality and residence information differs across countries. It includes those origins that account for most filings under the PCT. For the majority of countries shown, coverage lies above 90% and for most others, it is above 80%. US applications stand out as showing the lowest coverage, of around 66%. 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.

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

[18] The PCT rule changes that.

However, US applicants generally file their applications at the US 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 1 Total Records and Coverage of Nationality and Residence Information (selected countries)

Country/territory name	Total records	Records with information	Records of inventors only	Coverage (%)
Austria	40411	37755	1773	93.43
Australia	70720	67621	2491	95.62
Belgium	46488	41743	4200	89.79
Brazil	14116	12983	947	91.97
Canada	112627	91166	20399	80.95
Switzerland	84521	78600	4847	92.99
China	233506	213837	18684	91.58
Germany	751509	712426	35547	94.80
Denmark	46493	42097	4115	90.54
Spain	51020	48440	2085	94.94
Finland	64450	59677	4464	92.59
France	248541	233372	13030	93.90
United Kingdom	257266	236760	15807	92.03
Israel	63644	58599	4682	92.07
India	50777	45552	4656	89.71
Italy	95691	90309	4726	94.38
Japan	909360	854176	42204	93.93
Netherlands	128236	94616	22773	73.78
Norway	24294	23139	978	95.25
New Zealand	11806	11258	433	95.36
Russian Federation	39865	35590	3869	89.28
Sweden	114614	101894	12134	88.90
Singapore	18053	16270	1469	90.12
United States of America	2130268	1402203	703389	65.82
South Africa	10594	10015	502	94.53

Similar to Figure 1, Appendix Figure A1 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 of September 16, 2012, the ability of PCT records to provide information on inventors' migratory background appears seriously undermined.

4. Database Structure[19]

The database on immigrant inventors consists of 12 files, available in both STATA and .csv formats. The tables in these files include information for 241 countries/territories and 35 years of PCT filings.[20] Note that the year reference in these files refers to the priority date of the patent – that is, the first year in which the applicant filed the patent anywhere; this may be different from the year of PCT filing.

Of the 12 tables, 9 are relational in nature, and the remaining ones include attribute variables. The relational tables contain the bilateral "flows" of inventors, by year and country/territory pair. In particular, each row counts the number of PCT filings by inventors that are nationals of an origin country/territory (iso2_ori) and that reside in a destination country/territory (iso2_des), by year of priority filing. File 1 "Bilateral flows" contains these figures without any further breakdown. The rows where the origin and destination country codes coincide count the number of native inventors residing in their country of origin.

Files 2 to 4 present the same figures, but broken down by applicant type, including "Individual patentees", "Corporations" and "Research Institutions", with the latter consisting of universities and public research institutes. Note that when adding up figures from files 2 to 4 the resulting values are lower than in file 1, due to the fact that, for some patents, we were not able to identify the applicant type – especially for PCT applications filed before 1993.[21]

Files 5 to 9 again contain the same figures, but break them down by technology field. In particular, we use International Patent Classification (IPC) codes to assign each patent to

[19] All the data presented in this paper are available free of charge. Please cite this paper when using the data as follows: Miguelez, E. and Fink, C. (2012) "Measuring the international mobility of inventors: a new database" WIPO Economic Research Working Paper No. 8. The paper, datasets and other technical information are available at http://www.wipo.int/econ_stat/en/economics/publications.html.

[20] We follow the official classification of countries/territories of the United Nations, as well as the date they become an official country/territory: http://unstats.un.org/unsd/methods/m49/m49alpha.htm (accessed 9th May 2013).

[21] In order to assign each patent to an applicant type, we rely on a methodology developed internally at WIPO. This methodology first searches for university- and research institutions-related keywords in the applicant fields – for example, "University", "Université", "Uni.", and others. Based on this search, it assigns the category "university" or "research institutions" to a number of applicants. The remaining applicants are assumed to be either corporations or individuals. The identification of applicants is conservative, in the sense that all research institutions or universities with names not appearing in the keyword list are automatically classified as corporations. In addition, the procedure is only applied to the first applicant of each patent. These two limitations, alongside the fact that some academic inventors may assign their patents to corporations, lead to an underestimation of the number of inventors from universities and research institutions. In addition, WIPO only started to clean applicant names in 2004. While some applicant type data are also available prior to 2004, they are in general less reliable; no applicant type data are available prior to 1993.

one or more technology fields. In order to link each IPC code to a technology field, we follow the concordance developed by Schmoch (2008). This concordance groups IPC codes into 35 technology fields. We further group these fields into 5 broad technology groups, namely "Electrical engineering", "Instruments", "Chemistry", "Mechanical engineering", and "Other fields". Note that when adding up the figures in files 5 through 9 the resulting values are higher than in file 1, due to the fact that some patents may belong to two or more different technological fields.

Files 10 and 11 present inventor emigration rates for 2 time windows – 1991-2000 and 2001-2010. The inventor emigration rate of origin country/territory *i* is defined through the following formula:

$$em\_rate_i = \frac{diaspora_i}{residents_i + diaspora_i} ,$$

whereby "diaspora" is the number of national inventors of country/territory i that are residing abroad, and "residents" is the number of inventors residing in country/territory i, including both nationals of country/territory i and immigrants.

Finally, file 12 provides the list of countries/territories available in our database, including the official name of the country/territory, the ISO code (2 and 3 digits), the world region it belongs to, the continent it belongs to, its income group, and whether it was an OECD member in 2012.[22] Figure 2 summarizes the content of each file and depicts how to link tables so that users can extract data according to their needs.

Figure 2 Content and Structure of the Dataset

Bilateral flows	
iso2_ori	Country/territory of origin code iso2
prio_year	Priority year (first filing) of the patent application
iso2_des	Country/territory of destination code iso2
flow	Count number records residents in iso2_des and nationals of iso2_ori

Emigration rates	
iso_alpha2_code	ISO 2-alpha country/area codes (2-digit)
residents10_XX_XX	# of resident inventors' names, 10-year window
diaspora10_XX_XX	Diaspora size, 10-year window
em_rate10_XX_XX	Emigration rate, 10-year window

List of countries or territories, and classifications	
iso_alpha2_code	ISO 2-alpha country/area codes (2-digit)
iso_alpha3_code	ISO 3-alpha country/area codes (3-digit)
territory_name	Official name of the country/territory
region	World region the country/territory belongs to
continent	"Continent the country/territory belongs to
income	Income level, World Bank classification 2012
oecd	OECD membership 2012 (yes/no)
iso2_ori	Country of origin code iso2
iso2_des	Country of destination code iso2

[22] World regions include: East Asia and the Pacific, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, North America, South Asia, and Sub-Saharan Africa. The continents considered include: Africa, Asia, Europe, Latin America and the Caribbean, North America, and Oceania and the Pacific. The

5. Descriptive overview

This section presents a first descriptive overview of our dataset. In particular, we focus on inventor immigration and emigration rates in different parts of the world and identify the most important bilateral migration corridors.

We find exceptionally high migration rates for inventors. To motivate this, we recall that the prior literature has estimated a global migration rate in 2000 for the population of age 25 and older of 1.8%. It has also established that the migration rate increases with migrants' skills; in particular, estimates suggest a 1.1% migration rate for the unskilled population, a 1.8% rate for the population with secondary education, and a 5.4% rate for the population with tertiary education.[23] Our data, in turn, point to an inventor migration rate of 8.62% in 2000 – taking the skills bias in the propensity to migrate one step further.

Figure 3 depicts the evolution of the share of inventor names in PCT patent applications with migratory background for the world as a whole and for selected continents. As can be seen, the share of migrant inventors has steadily increased over time. 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 highly-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.[24]

Figure 3 Share of Immigrant Inventors, 1985-2010

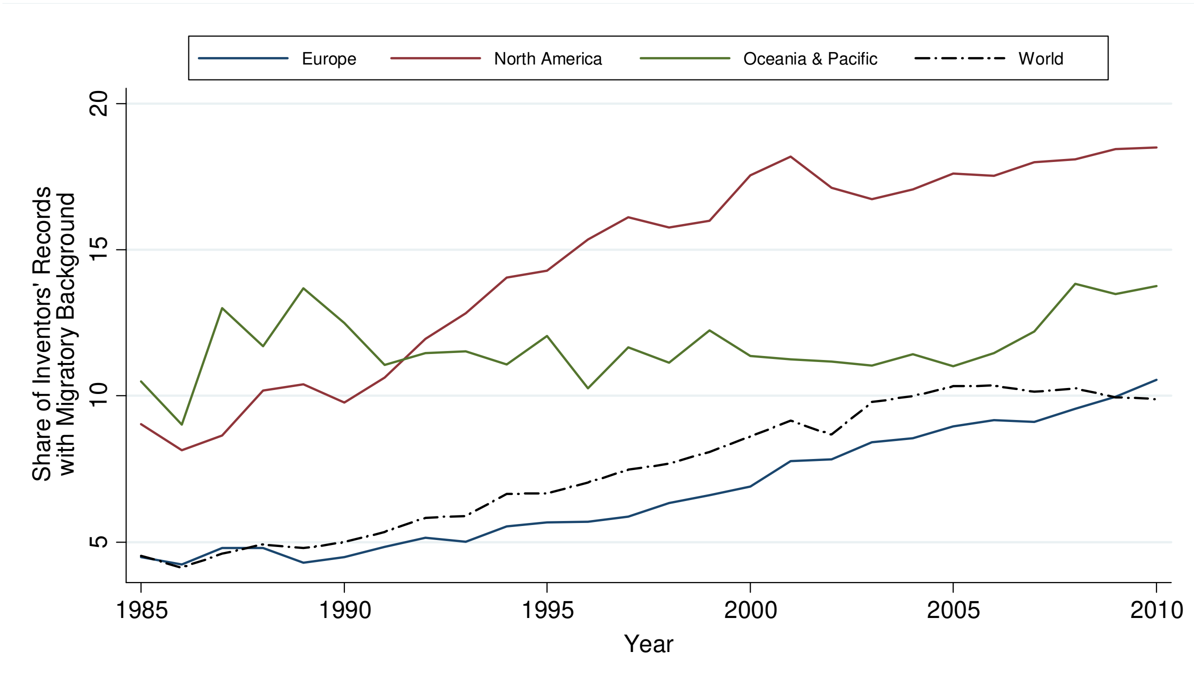


Figure 4 shows the same inventor immigration shares for selected countries and confirms this point. In particular, Australia, Canada and especially the US stand out as the primary receiving countries relative to their population of inventors.

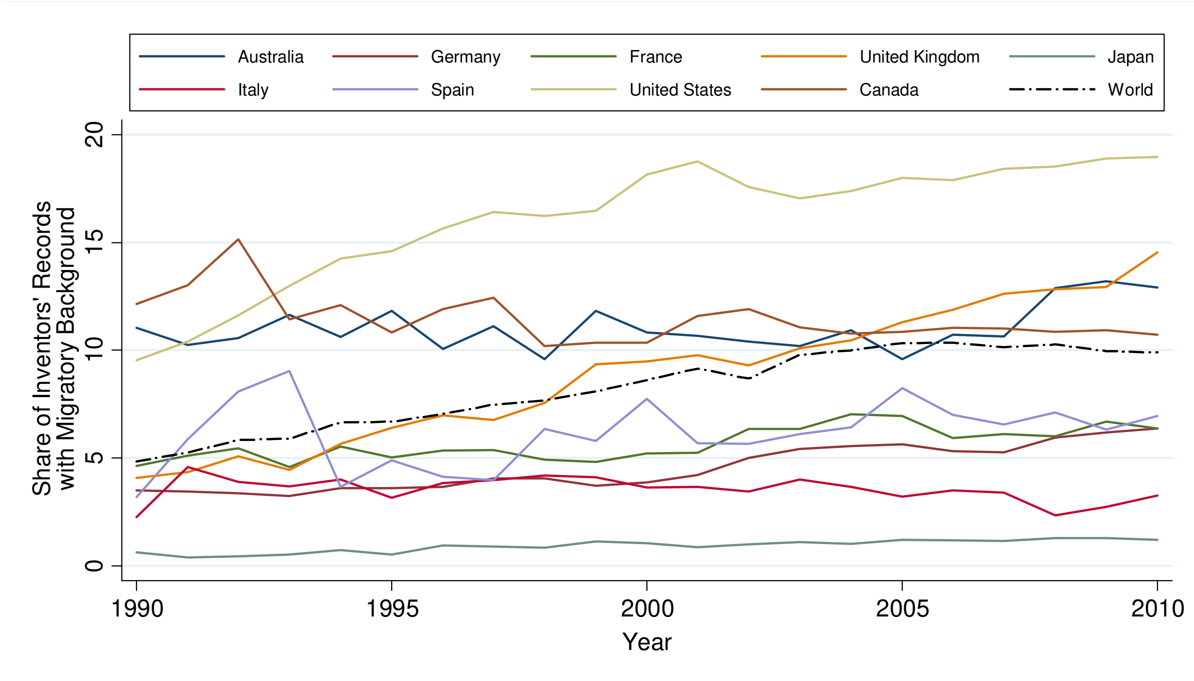
income groups considered, according to the World Bank classification in 2012, are: high income, low income, lower middle income, and upper middle income.

[23] See Docquier and Marfouk (2006) and Beine et al. (2007).

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

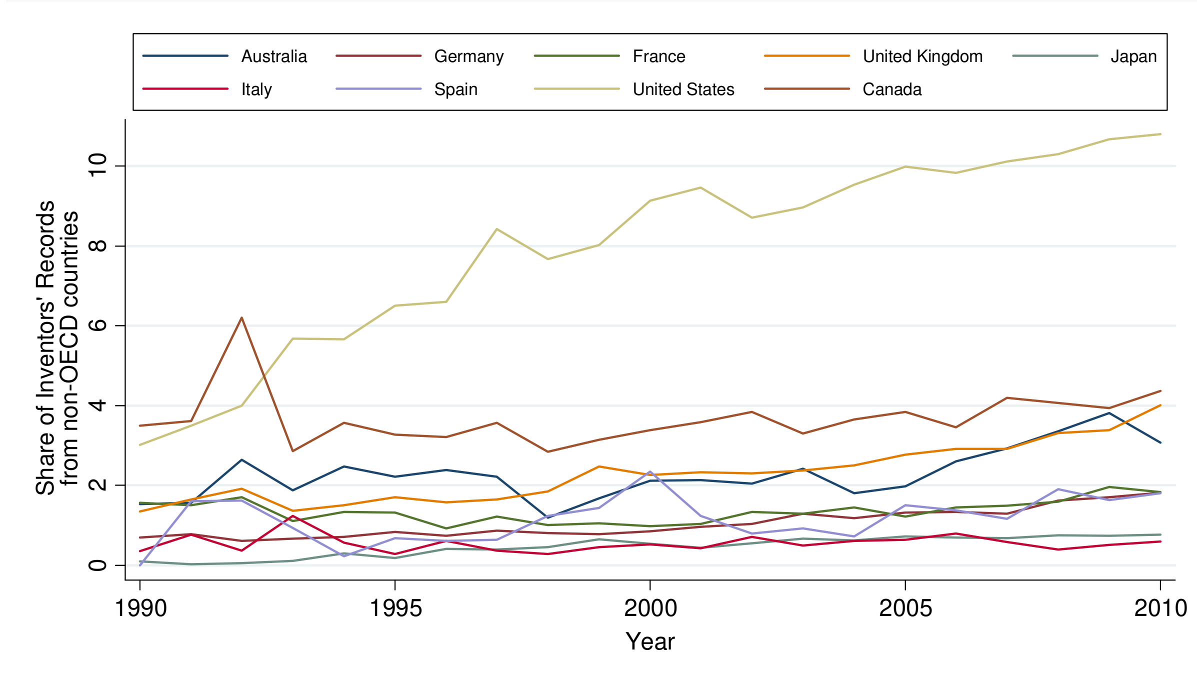
While at the forefront of technological innovation, Germany and France have consistently seen lower inventor immigration rates. Of special interest is the UK, which has experienced a substantial increase in its share of immigrant inventors. Japan, in turn, remains the only high income economy with an inventor immigration rate of less than 2%.

Figure 4 Share of Immigrant Inventors, 1990-2010



The exceptional performance of the US in attracting talent can be further seen in Figure 5, where we compute the same variable for these selected countries, but consider only immigrant inventors coming from non-OECD countries. The figure illustrates the South-North "brain drain" of inventors. As can be seen, most countries exhibit relatively stable immigration rates, except the US, the UK and – especially since 2005 – Australia. Interestingly, comparing Figures 4 and 5, the lead position of the US is more pronounced when only looking at non-OECD 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 countries.

Figure 5 Share of Immigrant Inventors, 1990-2010 (Immigrants from OECD Countries Excluded)



Note: For the calculation of immigration rates, we include Mexico and Chile – as the only middle income OECD countries – among the sending countries. Removing these countries and re-calculating the rates does not change the results to a large extent.

Table 2 provides similar figures for the time periods 1991-2000 and 2001-2010 and includes a larger set of receiving countries. It shows that relatively small countries such as Belgium, Ireland, Luxembourg, New Zealand and Switzerland rely more heavily on foreign inventors, though overwhelmingly from other OECD countries. The US stands out as the only large country with a comparably high inventor immigration rate and, as already pointed out, the country with the largest share of inventor immigrants from non-OECD countries. For comparison purposes, the right-hand column of Table 2 provides immigration rates of college graduates using census data. It shows a US immigration rate far more in line with other large OECD countries, suggesting that the special popularity of the US is somewhat unique to inventors.

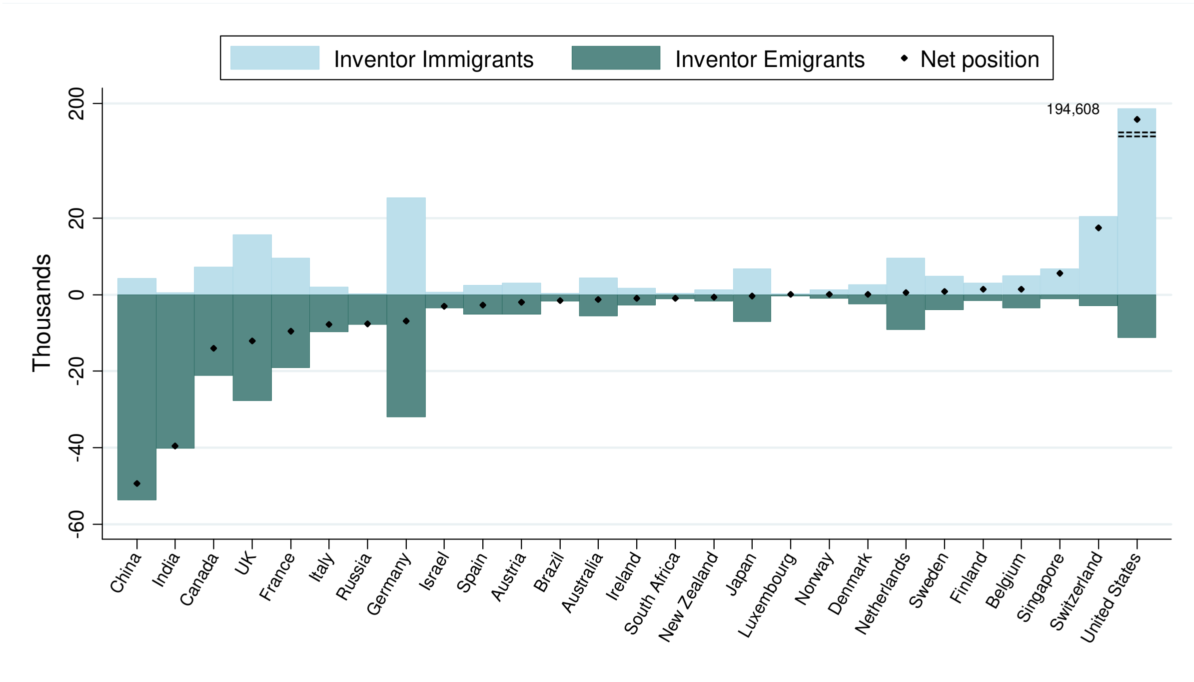
Related to the former figures, it is also worth looking at the net balance of immigrant and emigrant inventors for selected countries. Figure 6 depicts for the 2001-2010 period the number of immigrant and emigrant inventors and orders countries according to their net immigration position. Again, the US stands out in showing by far the largest immigration surplus; indeed, there are more than fifteen times as many immigrant inventors in the US as there are US inventors residing abroad. By contrast, Canada and the three largest European economies – namely, France, Germany and the UK – see negative net immigration positions. The cases of Germany and the UK are especially interesting, as they host considerable numbers of immigrant inventors, but even greater numbers of German and UK inventors residing abroad.

Table 2 Immigration Rates of Selected Countries, 1991-2000 and 2001-2010, in percent

Country	All inventors 1991-2000	All inventors 2001-2010	Non-OECD inventors 1991-2000	Non-OECD inventors 2001-2010	College graduates (census) 2000
	(i)	(ii)	(iii)	(iv)	(v)
Austria	8.80	12.45	0.59	1.57	14.33
Australia	10.89	11.20	2.02	2.67	33.17
Belgium	16.89	18.56	1.58	1.94	10.61
Canada	11.16	11.03	3.49	4.07	25.84
Switzerland	28.45	38.41	2.08	3.05	28.38
Germany	3.76	5.54	0.80	1.39	11.39
Denmark	5.07	9.98	0.40	1.61	8.00
Spain	5.95	6.72	1.35	1.43	6.38
Finland	2.93	8.74	0.94	3.69	2.25
France	5.12	6.32	1.17	1.52	12.38
U.K.	7.17	11.62	1.95	3.03	16.00
Ireland	17.38	19.89	1.62	4.93	18.07
Italy	3.88	3.27	0.49	0.60	6.11
Japan	0.87	1.15	0.41	0.68	1.05
Luxembourg	23.14	35.42	2.10	2.86	49.04
Netherlands	7.80	13.77	0.74	3.31	11.36
Norway	4.96	9.17	0.54	1.30	8.09
N. Zealand	14.72	16.60	1.63	3.24	24.85
Sweden	4.61	8.44	1.07	2.12	14.26
U.S.	16.07	18.18	7.87	10.24	13.86

Note: For the calculation of immigration rates in columns (iii) and (iv) we include Mexico and Chile – as the only middle income OECD countries – among the sending countries Removing these countries as sending countries only leads to minor changes in the immigration rates. Data to compute the immigration rate of college graduates in selected countries (column v) are from the OECD's DIOC-E database, except Germany were we rely on the data provided in Beine et al. (2009).

Figure 6. Net Migration Position, 2001-2010



We next turn to inventor emigration patterns and trends. Recall that the prior literature has estimated a 5.4% 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 3.6%, compared to 7.3% in low- and middle-income countries. It was much higher for least developed countries (13.1%) and for small island developing states (42.4%).[25]

These differences turn out to be even more marked when looking at inventor data. The global share of inventor names with migratory background stood at 7.46% from 1991 to 2000, and at 9.94% from 2001 to 2010. However, the emigration rate of high income countries for these two time periods only stood at 4.99% and 5.92%, respectively.[26] It was much higher for low- and middle-income countries – standing at 41.73% and 36.40%, respectively.[27]

Figure 7 depicts the evolution of emigration rates both for the world and for individual continents. It shows that Africa as well as Latin America and the Caribbean by far exhibit the highest emigration rates. In 2010, around half of African inventors lived outside their home country.

Figure 7 Emigration Rates, 1995-2010

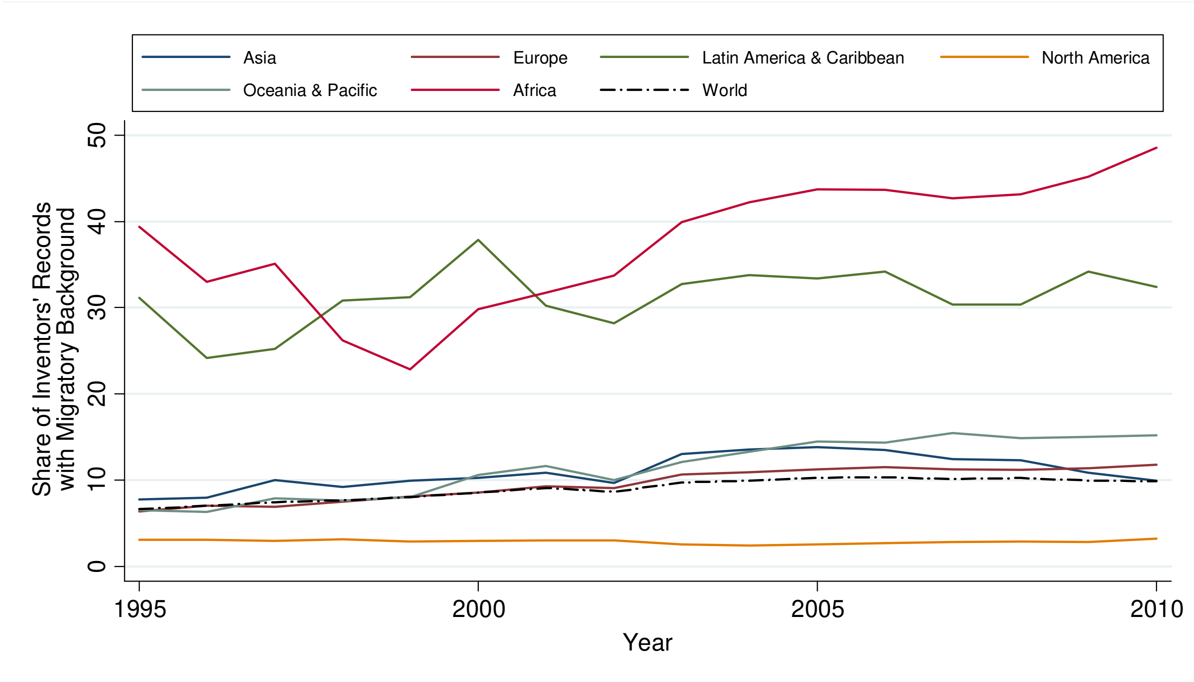


Table 3 and 4 provide top-30 lists of immigrant counts, emigrant counts, and emigration rates for the time periods 1991-2000 and 2001-2010, respectively. Unsurprisingly, the top-30 immigrant list consists mostly of high income economies, probably reflecting the attractive employment, education, research, and entrepreneurship opportunities offered by these economies. Interestingly, most high income countries also show sizeable diasporas abroad, although China and India come out as the top two inventor sending countries in the 2001-2010 period. When looking at relative emigration rates – which take into account size of the

[25] As extracted from 2000 census data; see Docquier and Marfouk (2006) and Docquier et al. (2007).
[26] We report emigration rates as defined in Section 4.
[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.

local inventor endowments – low- and middle-income countries dominate the top-30 list, especially small and African economies.

Table 3 Immigrants, Emigrants and Emigration Rates, 1991-2000

Country/ territory	Immig.	Nationals	Country/ territory	Emigrants	Residents	Country/ territory	Emig. rates
US	31358	163725	UK	8930	73166	Iraq	1.00
Germany	6887	176311	China	8206	6775	Ethiopia	1.00
UK	5248	67918	Germany	7216	183198	Nepal	1.00
Switzerland	4544	11428	India	5193	1552	Myanmar	1.00
France	2909	53934	France	3350	56843	Guyana	1.00
Australia	2051	16791	Canada	3286	17410	Banglad.	0.99
Canada	1943	15467	US	3205	195083	Pakistan	0.98
Belgium	1760	8661	Italy	2068	18514	Nigeria	0.97
Japan	1376	156488	Austria	1993	8179	Iran	0.97
Sweden	1340	27700	Netherl.	1986	16991	Lebanon	0.95
Netherl.	1325	15666	Russia	1662	11973	Ghana	0.95
Austria	720	7459	Japan	1237	157864	Libya	0.94
Italy	719	17795	Belgium	1235	10421	Cameroon	0.94
Singapore	668	843	Australia	1224	18842	Algeria	0.94
Denmark	547	10247	Sweden	1160	29040	Tunisia	0.93
Finland	501	16610	Switzerland	951	15972	Viet Nam	0.92
N. Zealand	452	2618	Spain	927	6953	A. Barbuda	0.92
Israel	439	11299	Ireland	906	2342	Tanzania	0.92
Spain	414	6539	Greece	770	631	Morocco	0.91
Ireland	407	1935	R. of Korea	763	11459	Ecuador	0.90
S. Africa	358	2360	Israel	733	11738	Mauritius	0.90
Norway	339	6500	Denmark	701	10794	Sri Lanka	0.90
China	249	6526	Iran	604	18	Jordan	0.90
Brazil	168	1541	N. Zealand	584	3070	Jamaica	0.88
Monaco	148	0	Finland	561	17111	Togo	0.86
Luxemb.	121	402	Poland	536	1017	Albania	0.86
Liechten.	77	36	Norway	419	6839	Guatemala	0.82
Mexico	74	520	Turkey	400	483	Syria	0.82
Hungary	72	3779	Malaysia	395	152	Egypt	0.82
Bahamas	71	0	Hungary	377	3851	T.& Tob.	0.79

Note: The last column shows the emigration rates only if the country has at least 10 nationals (both abroad and residents).

Table 4 Immigrants, Emigrants and Emigration Rates, Time Window 2001-2010

Country/ territory	Immig.	Nationals	Country/ territory	Emigrants	Residents	Country/ territory	Emig. rates
US	194609	875962	China	53610	141902	Mauritania	1.00
Germany	25341	432136	India	40097	38486	Afghanis.	1.00
Switzerland	20416	32737	Germany	32158	457477	Tonga	1.00
UK	15758	119824	UK	27746	135582	Rwanda	1.00
Netherl.	9665	60513	Canada	21315	65808	Eritrea	1.00
France	9540	141413	France	19123	150953	Nicaragua	1.00
Canada	7257	58551	US	11131	1070571	Ethiopia	1.00
Singapore	6720	6311	Italy	9820	62973	Mauritius	0.99
Japan	6715	578101	Netherl.	9132	70178	Uganda	0.98
Belgium	5042	22122	R. of Korea	9127	164078	Laos	0.98
Sweden	4832	52451	Russia	7878	20561	Nepal	0.98
Australia	4427	35088	Japan	6986	584816	Nigeria	0.98
China	4251	137651	Australia	5631	39515	Banglad.	0.98
Austria	3113	21896	Spain	5154	35786	Niger	0.97
Finland	3095	32314	Austria	5122	25009	Guyana	0.97
Denmark	2589	23364	Sweden	4025	57283	Myanmar	0.97
Spain	2406	33380	Israel	3668	42001	Iran	0.97
Italy	2060	60913	Belgium	3567	27164	Iraq	0.97
Ireland	1689	6803	Greece	3209	2025	Haiti	0.96
R. of Korea	1472	162606	Turkey	3119	6202	Honduras	0.96
N. Zealand	1249	6277	Switzerland	3005	53153	Yemen	0.96
Norway	1245	12327	Ireland	2686	8492	Cambodia	0.94
Israel	694	41307	Malaysia	2682	4154	Ghana	0.94
S. Arabia	569	524	Romania	2589	771	Suriname	0.94
India	532	37954	Poland	2537	4559	Dominica	0.93
Malaysia	524	3630	Denmark	2411	25953	Swaziland	0.93
S. Africa	426	6355	Iran	2253	76	Liberia	0.93
Brazil	376	9050	Ukraine	1911	2464	Congo	0.93
Luxemb.	322	587	Brazil	1859	9426	Pakistan	0.93
U.A.E.	273	54	N. Zealand	1839	7526	Tanzania	0.93

Note: The last column shows the emigration rates only if the country has at least 10 nationals (both abroad and residents).

Figure 8 and 9 depict emigration rates – or “brain drain” rates – in maps for the same two time periods. These maps confirm that low- and middle-income countries and especially African economies are the most severely affected by inventor “brain drain”.

Figure 8 Brain Drain Rates, 1991-2000

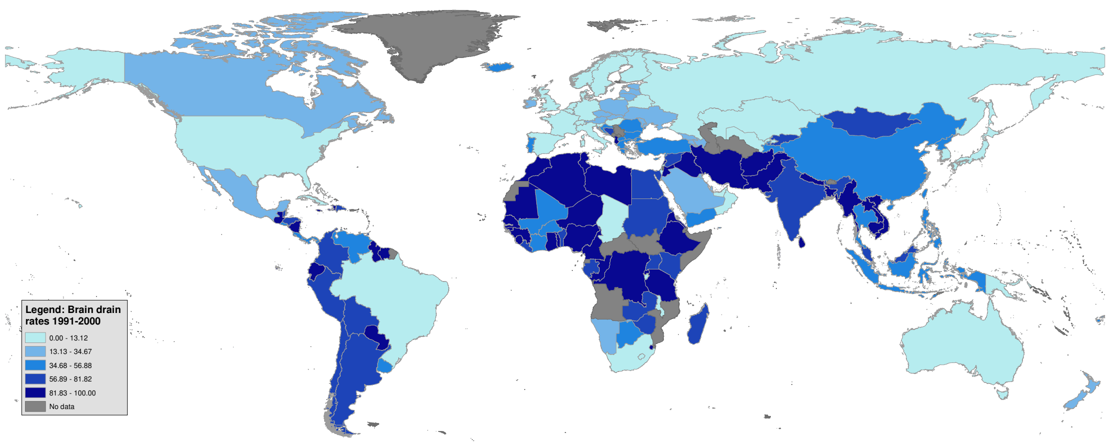
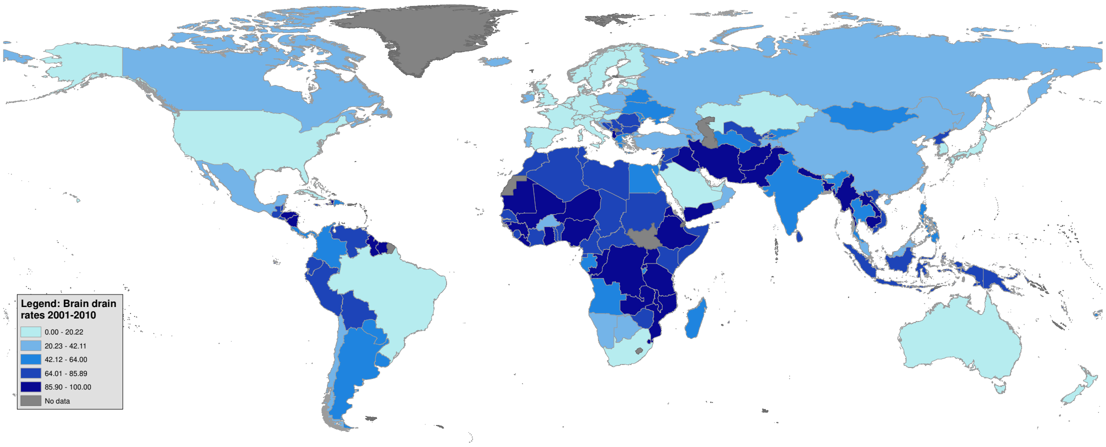


Figure 9. Brain drain rates, 2001-2010



Due to the bilateral nature of our data, we can identify the main inventor migration corridors. The left hand side of Tables 4 and 5 lists the 30 most important corridors for the 1991-2000 and 2001-2010 periods, respectively. These 30 corridors account for only 0.08% of country/territory pairs in our dataset. However, they represent 51.76% and 58.70% 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 countries. In line with Figures 4, the US appears most frequently in this list as a destination country.[28]

The right hand columns in Tables 5 and 6 list the 30 most important corridors for which the sending country is not an OECD member. This allows us to look more carefully at South-North migration, and possibly also South-South migration. As in Figure 5, 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, confirming the earlier finding that European countries lag behind in attracting inventors from non-OECD countries.[29] 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.

[28] This also holds for the general population of migrants (see Docquier et al., 2011).
[29] See Docquier and Rapoport, 2009.

Table 5 Largest Inventor Migration Corridors, 1991-2000

Largest inventor migration corridors			**Largest inventor migration corridors, limited to non-OECD sending countries**		
Origin	**Destination**	**Counts**	**Origin**	**Destination**	**Counts**
China	United States	6279	China	United States	6279
India	United States	4470	India	United States	4470
UK	United States	4249	Russia	United States	842
Canada	United States	2652	China	Japan	402
Germany	United States	2055	China	UK	328
Germany	Switzerland	1786	China	Germany	311
Austria	Germany	1362	Iran	United States	233
France	United States	1003	Argentina	United States	209
Japan	United States	857	Iran	Germany	204
Russia	United States	842	China	Canada	203
UK	Germany	780	Russia	Germany	187
UK	Australia	576	China	Singapore	181
Australia	United States	569	Turkey	United States	178
R. of Korea	United States	546	Mexico	United States	166
Israel	United States	522	Brazil	United States	152
France	UK	513	China	Australia	135
United States	UK	490	Bulgaria	United States	128
Germany	UK	476	Ukraine	United States	126
United States	Canada	437	Serbia and Montenegro	United States	125
United States	Germany	436	India	Japan	123
UK	France	435	India	UK	121
Germany	France	432	Turkey	Germany	118
Switzerland	United States	431	Malaysia	United States	114
Italy	United States	430	China	Sweden	111
Germany	Austria	429	India	Canada	110
Sweden	United States	426	India	Singapore	108
Netherlands	United States	420	Malaysia	Singapore	100
Ireland	UK	419	Tunisia	France	94
Italy	Germany	416	Chile	United States	94
France	Switzerland	406	Pakistan	United States	86

Note: We include Mexico and Chile – as the only middle income OECD countries – among the sending countries.

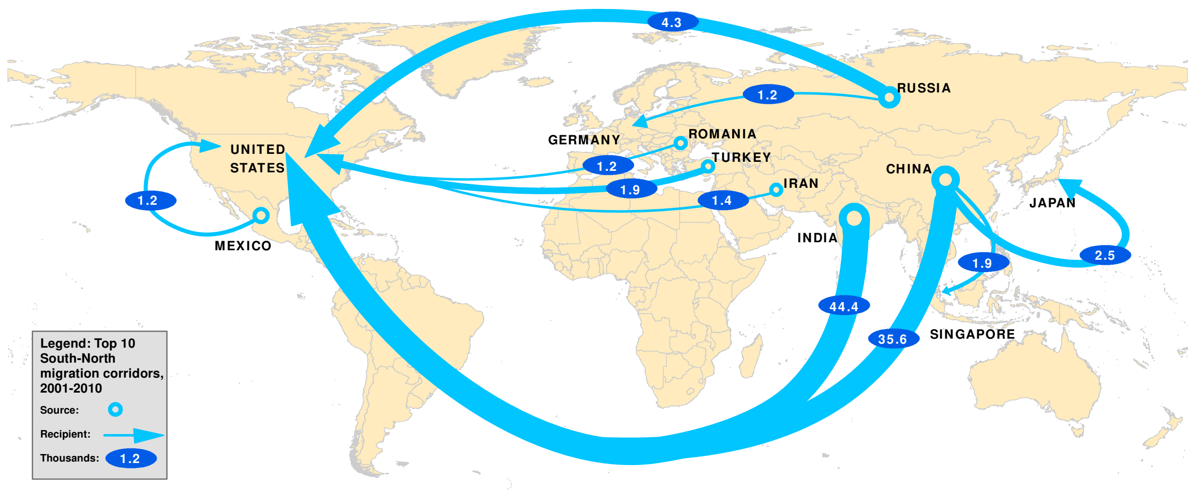
Table 6. Largest inventor migration corridors, 2001-2010

Largest inventor migration corridors			Largest inventor migration corridors, limited to non-OECD sending countries		
Origin	**Destination**	**Counts**	**Origin**	**Destination**	**Counts**
China	United States	44452	China	United States	44452
India	United States	35621	India	United States	35621
Canada	United States	18734	Russia	United States	4339
UK	United States	14893	China	Japan	2510
Germany	United States	10297	China	Singapore	1923
Germany	Switzerland	8198	Turkey	United States	1922
R. of Korea	United States	7267	Iran	United States	1438
France	United States	6543	Romania	United States	1220
Japan	United States	5045	Russia	Germany	1207
Russia	United States	4339	Mexico	United States	1161
Australia	United States	3241	Brazil	United States	1115
Israel	United States	2966	Malaysia	Singapore	1090
France	Switzerland	2747	Ukraine	United States	977
Netherlands	United States	2698	China	UK	920
Austria	Germany	2672	China	Germany	892
France	Germany	2607	India	Singapore	847
China	Japan	2510	Argentina	United States	820
Italy	United States	2501	Singapore	United States	775
Germany	Netherlands	2285	Malaysia	United States	729
Netherlands	Germany	2138	South Africa	United States	719
France	UK	2044	Egypt	United States	667
UK	Germany	2043	China	Canada	652
China	Singapore	1923	Bulgaria	United States	626
Turkey	United States	1922	Pakistan	United States	626
Germany	Austria	1829	Turkey	Germany	601
Germany	UK	1612	India	UK	556
Germany	France	1609	India	Germany	542
Spain	United States	1559	Colombia	United States	532
UK	Switzerland	1555	Thailand	United States	494
Italy	Switzerland	1536	Philippines	United States	450

Note: We include Mexico and Chile – as the only middle income OECD countries – among the sending countries.

Finally, Figure 10 draws on the second column of Table 5, depicting the top 10 South-North migration corridors for 2001-2010. It graphically illustrates the importance of the US as a destination country, on the one hand, and of China and India as sending countries, on the other. It also shows Iran, Romania, and Turkey among the top sending countries.

Figure 10 Top 10 South-North Migration Corridors, 2001-2010



6. Conclusions

This paper describes a new global dataset on migrant inventors, which we built using information on inventor nationality and residence available in PCT applications. By using patent data to map the migratory patterns of highly-skilled workers, we can overcome some of the limitations faced by existing datasets on the world's migrant population.

In particular, our database covers a long time period, provides information on an annual basis, and includes a large number of sending and receiving countries. By focusing on inventors, we capture a group of highly-skilled workers of special economic importance and with more homogenous skills than tertiary-educated workers as a whole. Our dataset 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 our 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 we only observe 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.[30] 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.[31] Similarly, as this paper has pointed out, the propensity to patent abroad – and in particular through the PCT route – differs across countries, affecting the selection of inventors included in our dataset.

As is the case for most other migration datasets, we can only identify inventors with migratory background, but we do not know 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 our dataset misses inventors with migratory background that have become

[30] See Hall and Ziedonis (2001) and WIPI 2011 special theme.
[31] See Hall, Jaffe and Trajtenberg, 2005.

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 our 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, our data do not allow us to assess the severity of these biases. Researchers using our data should be aware of these limitations, especially when drawing policy conclusions.

Notwithstanding these caveats, we believe that our new database meaningfully captures a phenomenon of growing importance. Indeed, the descriptive overview presented in this paper suggests that our database is consistent with migratory patterns and trends as they emerge from census data. At the same time, our 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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Appendix

Figure A.1. Coverage of Nationality and Residence Information, Selected Countries

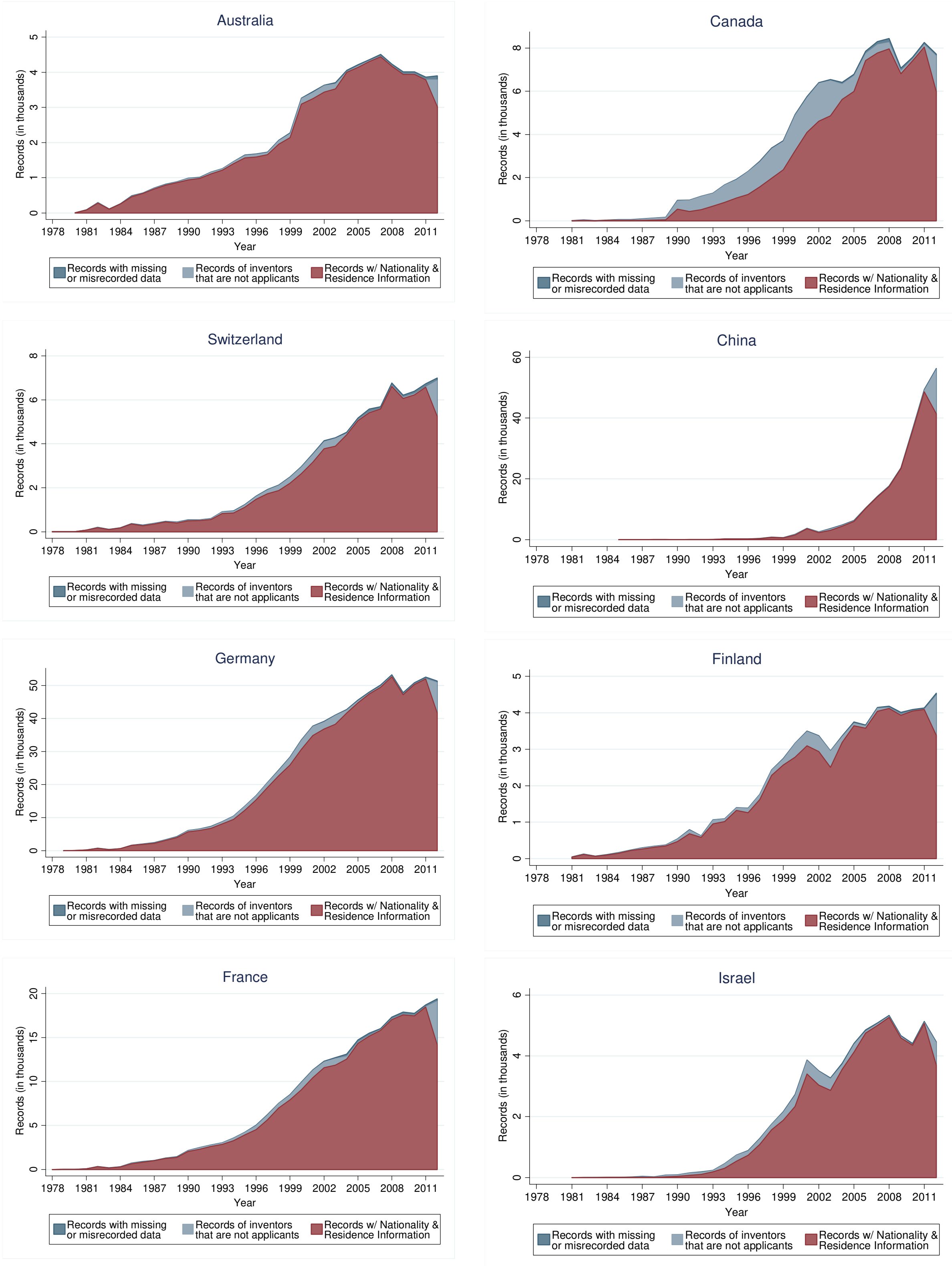

Figure A.1. (cont.)