SPECIAL SECTION THE INTERNATIONAL MOBILITY OF INVENTORS

Introduction

The relationship between migration and innovation has become a major focus of research by academics and policymakers alike. The key factor driving this development is the observation that high-skilled migrants decisively contribute to innovation outcomes, to the international diffusion of knowledge and, ultimately, to the economic growth of nations.

In some of the largest migrant-receiving countries (e.g., the United States of America (US)), immigrants are overrepresented among the most skilled workers. While immigrants account for about 12% of the entire US labor force, they account for 25% of US scientists and engineers, 50% of US PhDs, 60% of post-doctoral students, and 26% of US-based Nobel Laureates (Black and Stephan, 2008; Kerr, 2009). Some anecdotal evidence suggests that this overrepresentation of immigrants among high-skilled workers is not unique to the US, but extends to other countries that receive large numbers of migrants (Fink *et al*, 2013). Thus, an increasing, albeit still limited, number of studies have linked high-skilled immigration to knowledge creation (see Breschi *et al*, 2013; Kerr, 2013, for recent surveys). Given this situation, many countries are currently debating and reforming their immigration policies. A key question governments and policy makers face is how to attract skilled workers who can relieve domestic skills shortages and foster innovation.

This special section discusses the opportunities for using IP data and patent applications, in particular, for migration related research. It does so by describing the main patterns and trends in inventor international migration – data which were elicited from information contained in Patent Cooperation Treaty (PCT) applications. The next section briefly describes the source of the data, while the following sections more extensively analyze aggregated figures on the phenomenon of inventor migration and explore the possibilities of using these data for future research.

What can patent data tell us about skilled migration?

The literature on migration and innovation is limited, mainly due to the relative lack of data that have characterized this research field. In the last 15 years, census-based migration datasets have been the data source most commonly used to conduct research on migration issues as well as to study the migration-innovation nexus. These datasets comprise information on migrants by destination country based on population censuses. Notwithstanding their value for economic research, census-based datasets have certain limitations. For example, the data are only released every 10 years. Moreover, the majority of existing datasets provide a skills breakdown according to three schooling levels: primary, secondary and tertiary, which only offers a rough differentiation of skills.

More recently, information retrieved from patent documents has also been used for the purpose of undertaking innovation-migration research. Broadly speaking, patent applications contain relevant information on the inventors and owners of the patent, including the inventors'/owners' names and addresses, technologies (IPC classifications) and backward citations. Thus, patent data are an unrivalled indicator for studying a number of innovation-related phenomena, such as the mobility of inventors, their social networks and the patterns of knowledge diffusion. The potential benefits of using inventor migration data as captured in patent applications - which this section elucidates - are manifold. First, data are related to one specific class of high-skilled workers that are 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. The use of patent-inventor data for migration analysis implies the direct measurement of migrants, contribution to innovation in their destination countries'. Finally, patent data (and therefore inventor-related information) are collected on a yearly basis, and such data are available for a large number of "sending" and "receiving countries" at a relatively low cost.

Recently, scholars have undertaken studies of migrant inventors using information from patent applications (Breschi *et al*, 2013; Kerr, 2009). In particular, they have sought to identify the likely cultural origin of inventor names disclosed in patent data, which provides important insights. However, the cultural origin of inventor names may not always indicate recent migratory background – for example, Turkish immigrants in Germany.

PCT applications contain information on the nationality of inventors as well as information on their country of residence at (for a detailed description of the data source, see Miguélez and Fink, 2013). This information is available due to one of the requirements under the PCT specifying 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 requires applicants to provide details of both their nationality and their residency. Moreover, it transpires that, until 2012, US patent application procedures have required all inventors in PCT applications to be listed as applicants. Thus, if a given PCT application included the US as a country in which the applicant was considering pursuing a patent – a so-called designated state in the patent application – all inventors were listed as applicants, whereby ensuring that information on their residence and nationality were available. The majority of PCT applicants seek protection in the US, reflecting the popularity of this country as the world's largest market. As a result, these data offer a valuable resource to better understanding high-skilled migration flows and their implications for innovation.[1]

The PCT database comprises more than 6 million names of the inventors detailed in PCT applications. These names include some homonyms which may (or may not) refer to the same inventor. The database does not, however, provide a single identifier for each inventor, which makes it difficult to consolidate inventor names. For example, when two applications contain identical inventor names, it is difficult to distinguish whether they are filed by the same inventor or by two different inventors.

1 Unfortunately, the US enacted changes to its patent laws under the Leahy-Smith America Invents Act (AIA), which effectively removed the requirement that inventors also be named as applicants. Starting on September 16, 2012, PCT applicants (automatically) designating the US became free to list inventors and are no longer obliged to indicate their nationality and residence. As a result, many applicants do not provide such information any longer.

The economic literature has disambiguated individual inventors through their names and surnames as well as through other information contained in patent documents. This section does not attempt to disambiguate inventor names, and it treats each combination of the inventor name with an application number as if it were a different inventor. Although this approach is far from perfect, it enables meaningful analysis on an aggregate level.

Overall, the share of PCT data with information on nationality and residency was very high, i.e., approximately 80% for the 1978-2012 period. However, this coverage was unevenly distributed over time – approximately 60-70% during the 1990s and 70-95% during the 2000s. Coverage was also unevenly distributed across countries: US (66%), Canada (81%), the Netherlands (74%), Germany (95%), the United Kingdom (UK, 92%), France (94%), Switzerland (93%), China (92%) and India (90%), among others.

Using the inventor's nationality information outlined above, the following subsections present several migration-related figures. These figures clearly show that the pattern of inventor's mobility, especially from the perspective of the receiving countries, resembles other high-skilled migration figures, and in particular, what is known about the migration of scientists and engineers based on anecdotal evidence, surveys and media reports.

Where do migrant inventors emigrate to/come from?

Analysis of all records containing complete information has shown that approximately 5 million, i.e., 9-10% of inventors had a migration background – i.e., their place of residence was different from their nationality. This share has increased over time – it was 7.8% during the 1996-2000 period and 10.1% during the 2006-10 period.

Immigrant inventors were overwhelmingly concentrated in high-income countries, both during the 1996-2000 and 2006-10 periods (see Table 1). North America accounted for the highest concentration of immigrant inventors in high-income economies. During the period 2006-10, 59.1% of immigrant inventors were residing in North America – which is a share that is larger than that recorded during the late 1990s. A total of 31.4% of immigrant inventors lived in Europe over the 2006-10 period, which is lower than its 1996-2000 share. Asia lagged far behind, accounting for 7.5% of all immigrant inventors during the 2006-10 period.

Table 1: Shares of immigrant and emigrant inventors by income group and region: 1996-2000 and 2006-10

Income group / Region	Immigrant inventors (%) 1996-2000	Immigrant inventors (%) 2006-10	Emigrant inventors (%) 1996-2000	Emigrant inventors (%) 2006-10
Income group				
High-income	98.1	97.2	66.9	57.7
Upper middle-income	1.7	2.4	22.2	26.8
Lower middle-income	0.2	0.3	10.4	14.9
Low-income	0.1	0.1	0.5	0.6
Region				
Africa	0.5	0.1	1.8	1.7
Asia	5.0	7.5	31.8	41.9
Europe	39.3	31.4	52.0	41.9
Latin America and the Caribbean	0.7	0.3	2.2	2.7
North America	51.5	59.1	9.7	9.7
Oceania	3.1	1.5	2.5	2.1

Note: Income groups are defined according to the World Bank classification, 2012.

Source: WIPO Statistics Database, October 2013

Table 1 also presents the data from the perspective of the sending countries. The first interesting point to note is that the largest proportion of out-migration of inventors also occurred in high-income countries. However, the share of inventor emigrants from these countries was considerably lower when compared to the share of inventor immigrants. Indeed, middle-income countries accounted for more than 40% of emigrant inventors during the 2006-10 period. Moreover, when the data for the 1996-2000 and 2006-10 time periods are compared, it is possible to see that the contribution of middle-income economies increased considerably – i.e., approximately nine percentage points – while the corresponding share for high-income countries decreased by the same order of magnitude.

Like immigration, emigration was highly concentrated in two world regions, namely, Asia and Europe. Together these two regions accounted for more than 83% of inventor emigrants during the period 2006-10.[2]

Table 2 provides immigrant and emigrant data broken down by country. The majority of immigrant inventors were concentrated in the US, which accounted for 57.1% of all inventors during the 2006-10 period. European countries, such as France, Germany, Switzerland, the Netherlands and the UK, lagged far behind.

As can be observed, other high-income countries also accounted for large numbers of emigrant inventors; indeed, such countries were ranked among the top 20 in terms of having the largest emigrant communities. However, for the 2006-10 period, China and India topped the world ranking, followed by Germany and the UK. When compared with immigration patterns, emigrant inventors were more evenly distributed across countries. On the one hand, the US alone received approximately 57% of all immigrant inventors; on the other, six countries (Canada, China, France, Germany, India and the UK) hosted 57% of all emigrant inventors. Interestingly, countries such as Canada, France, Germany and the UK, despite being critical attractors of talent, saw more inventors emigrating than immigrating.

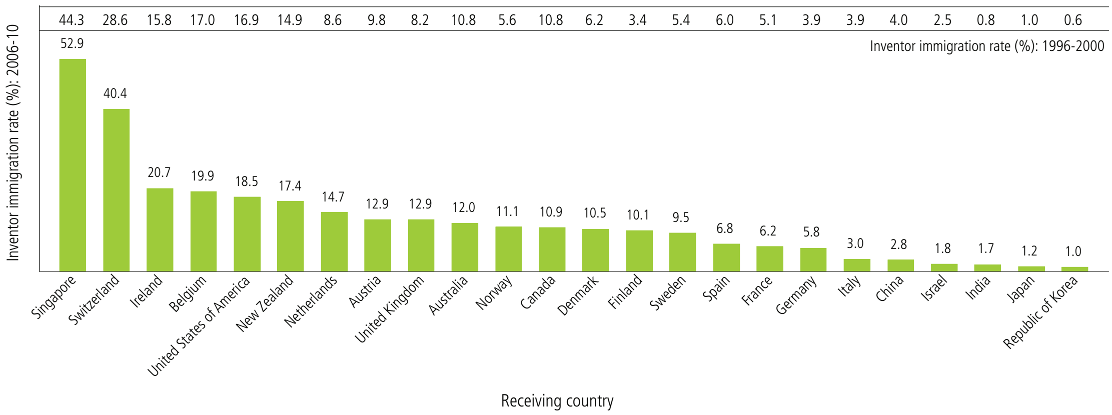
2 It should be noted that from the 1996-2000 period to 2006-10 period, the share of emigrant inventors from Asian countries increased considerably i.e., from 31.8% to 41.9%, while the share of European emigrant inventors decreased by approximately 10 percentage points between the same time periods (see Table 1).

Table 2: Top 20 countries with the largest inventor immigrant and emigrant communities, 2006-10

Country	Immigrants	Share of world total (%)	Country	Emigrants	Share over world total (%)
United States of America	117,244	57.1	China	33,413	16.3
Germany	14,547	7.1	India	24,807	12.1
Switzerland	12,479	6.1	Germany	19,043	9.3
United Kingdom	9,113	4.4	United Kingdom	15,160	7.4
Netherlands	5,565	2.7	Canada	13,056	6.4
France	5,369	2.6	France	11,790	5.7
Singapore	4,334	2.1	United States of America	6,795	3.3
Canada	4,107	2.0	Republic of Korea	6,101	3.0
Japan	4,092	2.0	Italy	6,092	3.0
China	3,289	1.6	Netherlands	5,052	2.5
Sweden	3,204	1.6	Russian Federation	4,404	2.1
Belgium	3,173	1.5	Japan	4,029	2.0
Australia	2,441	1.2	Australia	3,212	1.6
Finland	1,969	1.0	Spain	3,085	1.5
Austria	1,905	0.9	Austria	2,775	1.4
Spain	1,590	0.8	Sweden	2,506	1.2
Denmark	1,520	0.7	Israel	2,252	1.1
Republic of Korea	1,188	0.6	Turkey	2,046	1.0
Italy	1,108	0.5	Belgium	1,932	0.9
Ireland	1,092	0.5	Greece	1,886	0.9
World	**205,446**	**100**	**World**	**205,446**	**100**

Source: WIPO Statistics Database, October 2013

Figure 1: Inventor immigration rates for the largest receiving countries, 2006-10



Source: WIPO Statistics Database, October 2013

The US accounted for not only the largest absolute number of immigrant inventors, but it also had a high immigration rate of inventors, which is defined as total number of immigrant inventors over the total number of inventors (Figure 1). However, during the 2006-10 period, Singapore (52.9%) had the highest immigration rate, followed by Switzerland (40.4%), Ireland (20.7%) and Belgium (19.9%). Figure 1 also shows inventor immigration rates for the 1996-2000 period. Countries such as Denmark, Finland, Germany, Norway, Sweden, Switzerland, the Netherlands, and the UK recorded considerable increases in their immigration rates between the 1996-2000 and the 2006-10 periods.

Who recruits internationally?

In general, inventor immigration rates differ not only across countries, but also across different applicants. For example, Table 3 lists the immigration rates for the top 10 PCT applicants – based on the residence of the first-named applicant for the 2006-10 period for a selection of countries. It shows that the distribution of immigrant inventors was very uneven across applicants, even between enterprises of a relatively similar size. In France, for example, France Telecom's rate of immigrant inventors was between four and five times greater than that of Peugeot-Citroen – an imbalance which cannot be solely attributed to differences across technology fields. In another example, Peugeot-Citroen, had an immigration rate that was more than ten times greater than that of Renault S.A.S.

One interesting aspect of the data highlighted in Table 3 is the role played by universities and public research centers in the recruitment of talent from abroad. The top patenting universities and public research centers feature some of the highest inventor immigration rates among the top PCT applicants. This is the case for the University of California in the US, for example, and also for Cambridge University, Imperial Innovations (Imperial College London), and Isis Innovation (Oxford University) in the UK, among others.

Table 3: Inventor immigration rates for top 10 applicants, selected countries, 2006-10

Applicant's name	Immigration rate (%)	Applicant	Inventor
United States of America			
QUALCOMM INCORPORATED	50.8	6,528	19,907
MICROSOFT CORPORATION	57.4	3,020	11,297
3M INNOVATIVE PROPERTIES COMPANY	11	2,577	8,852
HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.	18.6	2,360	6,114
E.I. DUPONT DE NEMOURS AND COMPANY	17	2,118	5,916
INTERNATIONAL BUSINESS MACHINES CORPORATION	21.4	2,006	6,854
UNIVERSITY OF CALIFORNIA	28.2	1,754	5,598
MOTOROLA, INC.	23.4	1,573	4,488
PROCTER & GAMBLE COMPANY	10.2	1,540	4,953
BAKER HUGHES INCORPORATED	12.8	1,461	3,552
Switzerland			
NESTEC S.A.	56.4	619	1,781
F. HOFFMANN-LA ROCHE AG	46.6	564	1,385
NOVARTIS AG	62.6	489	1,179
SYNGENTA PARTICIPATIONS AG	66.6	308	972
ACTELION PHARMACEUTICALS LTD	30.2	272	879
ALSTOM TECHNOLOGY LTD	67.6	212	506
ABB RESEARCH LTD	65	201	529
SWISS FEDERAL INSTITUTE OF TECHNOLOGY	49.2	186	534
SIKA TECHNOLOGY AG	30.4	179	426
INVENTIO AG	23.6	174	338
Singapore			
AGENCY OF SCIENCE, TECHNOLOGY AND RESEARCH	62.2	791	2,690
NATIONAL UNIVERSITY OF SINGAPORE	57.6	213	735
NANYANG TECHNOLOGICAL UNIVERSITY	61.4	148	474
CREATIVE TECHNOLOGY LTD	21.6	88	217
NANYANG POLYTECHNIC	23	74	166
SINGAPORE HEALTH SERVICES PTE LTD	37.4	35	160
TEMASEK LIFE SCIENCES LABORATORY LIMITED	70.6	28	78
RAZER (ASIA-PACIFIC) PTE LTD	4.6	27	44
SIEMENS MEDICAL INSTRUMENTS PTE. LTD.	25	27	76
S*BIO PTE LTD	77.6	17	49
China			
ZTE CORPORATION	0.2	7,551	17,803
HUAWEI TECHNOLOGIES CO., LTD.	0.8	7,277	18,858
HUAWEI DEVICE CO., LTD.	0.2	570	1,372
TENCENT TECHNOLOGY (SHENZHEN) COMPANY LIMITED	0	419	1,014
ALCATEL SHANGHAI BELL CO., LTD.	0.4	380	1,095
CHINA ACADEMY OF TELECOMMUNICATIONS TECHNOLOGY	2	317	1,002
BYD COMPANY LIMITED	0	263	1,015
TSINGHUA UNIVERSITY	0.2	242	1,571
PEKING UNIVERSITY	0.2	215	818
DA TANG MOBILE COMMUNICATIONS EQUIPMENT CO., LTD.	0.6	205	688

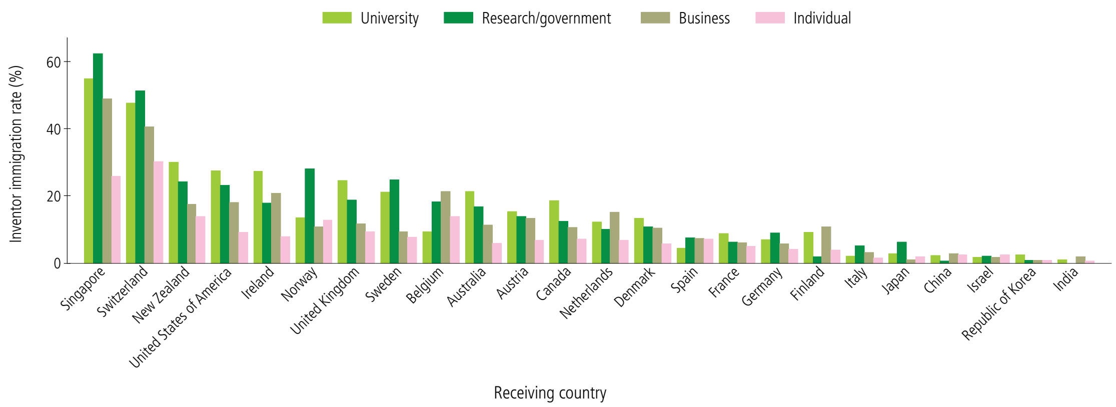
Source: WIPO Statistics Database, October 2013

Applicant's name	Immigration rate (%)	Applicant	Inventor
Germany			
ROBERT BOSCH CORPORATION	2.8	6,480	17,484
SIEMENS AKTIENGESELLSCHAFT	6.4	4,555	11,753
BASF SE	14.4	3,562	15,427
BOSCH-SIEMENS HAUSGERATE GMBH	3.2	1,679	4,575
FRAUNHOFER-GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	5.4	1,532	5,521
CONTINENTAL AUTOMOTIVE GMBH	8.6	1,337	3,447
HENKEL KOMMANDITGESELLSCHAFT AUF AKTIEN	6.4	1,210	4,420
DAIMLER AG	3.8	1,196	3,601
EVONIK DEGUSSA GMBH	5.6	974	4,103
ZF FRIEDRICHSHAFEN AG	2.4	958	2,702
United Kingdom			
UNILEVER PLC	10.4	594	1,536
GLAXO GROUP LIMITED	12.6	409	1,590
BRITISH TELECOMMUNICATIONS PUBLIC LIMITED COMPANY	20.2	389	861
BAE SYSTEMS PLC	3.2	305	644
IMPERIAL INNOVATIONS LTD.	29.8	246	648
ISIS INNOVATION LIMITED	29.8	242	618
DYSON TECHNOLOGY LIMITED	10.4	237	579
ASTRAZENECA UK LIMITED	8.2	210	640
CAMBRIDGE UNIVERSITY	36.6	205	572
QINETIQ LIMITED	2.2	185	458
France			
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)	8	1,892	7,002
COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	2.6	1,514	4,240
RENAULT S.A.S.	0.2	1,065	2,357
FRANCE TELECOM	11.6	963	2,188
L'OREAL	1.8	849	1,730
PEUGEOT CITROEN AUTOMOBILES SA	2.4	772	1,502
THALES ULTRASONICS SAS	0.4	626	1,473
INSTITUT NATIONAL DE LA SANTE ET DE LA RECHERCHE MEDICALE (INSERM)	9.2	517	1,633
ARKEMA	3.4	506	1,279
L AIR LIQUIDE SOCIETE ANONYME POUR L'ETUDE ET L'EXPLOITATION DES PROCEDES GEORGES CLAUDE	5	471	1,332
India			
COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH	0	304	1,477
HINDUSTAN UNILEVER LIMITED	1.4	178	602
RANBAXY LABORATORIES LIMITED	1.8	161	793
DR. REDDY'S LABORATORIES LTD.	0.8	134	891
CADILA HEALTHCARE LIMITED	0.8	128	455
LUPIN LIMITED	3.8	117	564
MATRIX LABORATORIES LTD	0	97	535
CIPLA LIMITED	0	87	257
INDIAN INSTITUTE OF TECHNOLOGY	0.6	82	200
WOCKHARDT LIMITED	1	75	323

What are inventors' preferred entrance routes?

Even if the evidence is only anecdotal, it seems reasonable to argue that universities and public research organizations act as privileged "points of entry" for high-skilled workers from abroad. Figure 2 explores this scenario by depicting inventor immigration rates across countries, broken down by four types of applicants: university; government and research institutions; business, and individuals. Bearing in mind that the business sector accounts for the vast majority (over 80%) of PCT applications (WIPO, 2012) in most of the countries listed in Figure 2, the university and government sectors accounted for the highest immigration rates. In selected cases, the university/government immigration rates were considerably higher than the business immigration rates – in particular, in Australia, Canada, Japan, Norway, Sweden, the Republic of Korea, the UK and the US. Only Belgium, China, Finland, India, Italy, the Netherlands and Spain did not report higher immigration rates for inventors working in academic institutions, as opposed to those working in commercial enterprises.

Figure 2: Immigration rates of inventors by type of applicant: business, university, research/government, and individual, 2006-10



Source: WIPO Statistics Database, October 2013

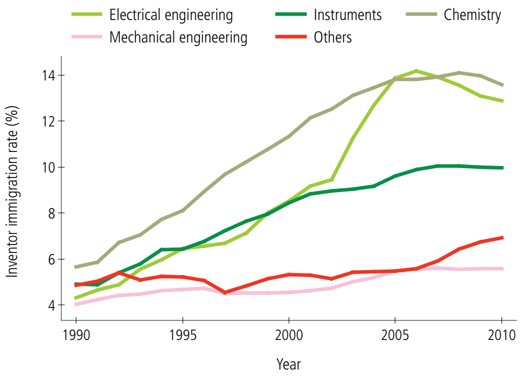
Do inventor immigration rates differ across technological fields?

As is apparent from analysis of applicant-level data, immigrant inventors' contribution to patenting differ markedly across technology fields. For example, inventors may be associated with one or more International Patent Classification (IPC) symbols, which in turn are grouped into 35 technology fields through the concordance table developed by WIPO.[3] It should be noted that when a PCT application relates to multiple fields of technology, the inventor is counted twice. Therefore, adding up the absolute numbers of inventors across the 35 technology fields results in a larger number of inventors than that outlined earlier in this report.

The 35 fields can be divided into broader technology groupings – electrical engineering, instruments, chemistry, mechanical engineering and others. As shown in Figure 3, all technology fields have recorded increases in the rates of immigration during the 1990-2010 period. However, electrical engineering and chemistry emerge as the most attractive sectors for foreign inventors. In contrast, the field of mechanical engineering has remained more or less stable.

3 WIPO has developed a concordance table in order to link IPC symbols to corresponding fields of technology (see *www.wipo.int/ipstats/en*).

Figure 3: Inventor immigration rates over time by field of technology: three-year moving averages



Source: WIPO Statistics Database, October 2013

Table 4 shows inventor immigration rates by field of technology for the 1996-2000 and 2006-10 periods. As can be seen, the differences across technology fields – in terms of how they relied on foreign inventors – were noticeable. Thus, for example, during the 2006-10 period, immigration rates varied from 4.1% (mechanical elements) to 18.3% (micro-structure and nano-technology). Other fields also relied heavily on immigrant inventors; such fields included pharmaceuticals (14.6%), biotechnology (14.6%), digital communication (15.2%), and basic communication processes (16%). The majority of technology fields had a higher inventor immigration rate for the 2006-10 period compared to the 1996-2000 period. Despite a decrease, both analyses of biomaterials and biotechnology fields showed a high inventor immigration rate for both periods.

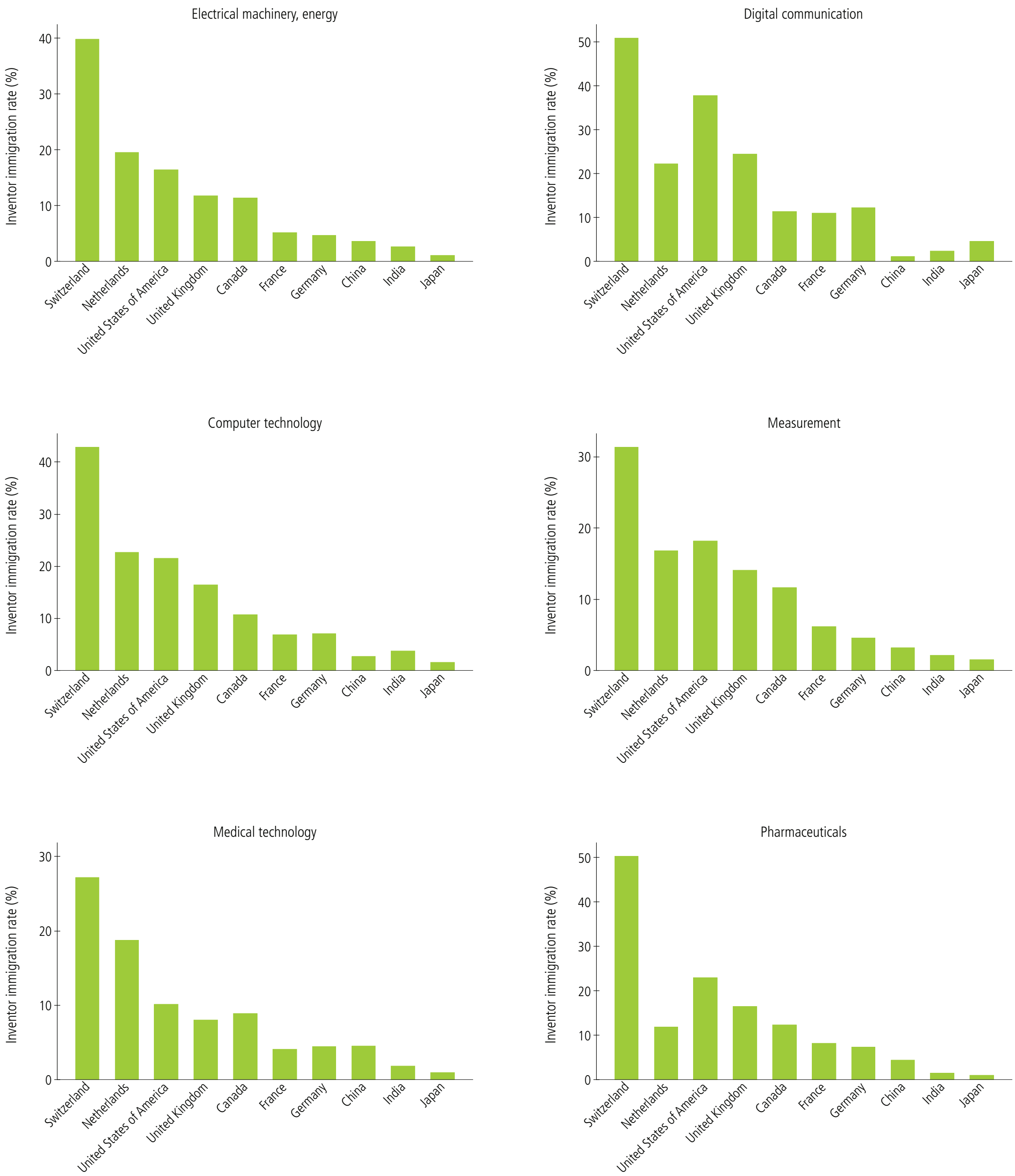
Table 4: Inventor immigration rates by technology field, 2006-10

Field of technology	Immigration rate (%), 1996-2000	Immigration rate (%), 2006-10
Electrical engineering		
Electrical machinery, energy	5.2	7.2
Audio-visual technology	6.2	9.5
Telecommunications	7.5	11.9
Digital communication	9.7	15.2
Basic communication processes	9.2	16.0
Computer technology	9.6	13.4
IT methods for management	8.0	10.5
Semiconductors	7.0	12.1
Instruments		
Optics	6.5	7.9
Measurement	7.0	9.8
Analysis of biological materials	13.9	13.8
Control apparatus	5.3	7.0
Medical technology	6.9	8.3
Chemistry		
Organic fine chemistry	9.3	13.9
Biotechnology	16.5	14.6
Pharmaceuticals	11.3	14.6
Macromolecular chemistry, polymers	7.2	10.2
Food chemistry	7.9	11.2
Basic materials chemistry	7.6	11.4
Materials metallurgy	5.7	7.7
Surface technology, coating	5.9	8.1
Micro-structure and nano-technology	13.0	18.3
Chemical engineering	6.5	9.0
Environmental technology	4.6	7.3
Mechanical engineering		
Handling	4.5	5.1
Machine tools	3.6	4.6
Engines, pumps, turbines	4.4	6.1
Textile and paper	5.1	6.8
Other special machines	5.0	6.4
Thermal processes and apparatus	4.3	5.2
Mechanical elements	3.8	4.1
Transport	3.9	4.3
Other fields		
Furniture, games	4.7	5.0
Other consumer goods	5.4	5.3
Civil engineering	4.4	7.7

Note: The IPC-technology concordance table (available at: *www.wipo.int/ipstats/en*) was used to convert IPC symbols into 35 corresponding fields of technology.

Source: WIPO Statistics Database, October 2013

Figure 4: Inventor immigration rates for selected technology fields and countries, 2006-10



Note: The IPC-technology concordance table (available at: *www.wipo.int/ipstats/en*) was used to convert IPC symbols into 35 corresponding fields of technology.

Source: WIPO Statistics Database, October 2013

Figure 4 reports inventor immigration rates for selected technology fields for a number of countries.[4] Generally, countries such as Switzerland, the Netherlands and the US had high inventor immigration rates in all of the reported fields for the 2006-10 period. In contrast, China, India and Japan reported low inventor immigration rates for the same period. However, across countries and technology fields, there were considerable variations in inventor immigration rates.

Do regions play a role in attracting talent?

One striking aspect of immigration, and particularly skilled immigration, is that migrants tend to concentrate in specific geographical areas within countries. For example, the share of skilled foreign-born individuals in the UK and France in 2000 was estimated at 8.8% and 9.8%, respectively; in contrast, 28% of London residents and 23% of Paris residents were foreign-born (Freeman, 2006). In particular, immigrant inventors appear to cluster in metropolitan areas, thus contributing to the spatial concentration of inventive activity. This issue is analysed by matching PCT applications with the OECD's REGPAT database (Maraut *et al*, 2008; refer to Miguélez and Raffo, 2013, for details of the matching procedure).[5] By linking inventor nationality information with REGPAT, it is possible to study the settlement patterns of immigrant inventors within countries beyond the settlement patterns of native inventors.

Table 5 lists the top 20 European NUTS 2 regions in terms of their inventor immigration rates.[6] It shows that European regions in highly innovative, middle-to-small European countries ranked well above the European average – although it should be noted that a few regions of the UK - a large European country - appear in this list. On the other hand, only six US states ranked above the national average; these six were, however, regarded as the most innovative and dynamic states. In order to compare regions of similar size from Europe and the US, it is worth repeating the analysis of the US data on a more disaggregated level, such as in the Metropolitan Statistical Areas (MSAs). In particular, some of the biggest and most innovative MSAs – San Diego, San Jose-Santa Clara, New York and Boston – appear in the top 20 ranking. When the MSA data are compared with the European NUTS 2 data, one can see that the top four European regions attract more talented individuals (in relative terms) than does San Diego.

However, only few European NUTS2 regions had an inventor immigration rate above 20%, while for the US a larger number of MSAs reported immigration rates greater than 20%. In other words, immigrant inventors' settlement in European regions seemed to be more skewed than was the case in the US.

4 The selection of technology fields was based on the total number of PCT applications filed in 2010.

5 The latest version of REGPAT provides detailed regional information on all EPO and PCT applicants, and information on inventors for all OECD and EU countries, as well as a few other selected countries.

6 NUTS stands for the French acronym "*Nomenclature des unités territoriales statistiques*".

Table 5: Top 20 immigration rates by region, 2006-10

NUTS2 region	Immigration rate (%)	US states	Immigration rate (%)	US MSAs	Immigration rate (%)
NORDWESTSCHWEIZ (CH)	50.7	CALIFORNIA	26.9	San Diego-Carlsbad-San Marcos, CA	36.7
RÉGION LÉMANIQUE (CH)	49.3	NEW JERSEY	24.2	Stockton, CA	33.3
RÉGION DE BRUXELLES (BE)	42.7	MASSACHUSETTS	21.8	Evansville, IN-KY	32.2
ZÜRICH (CH)	42.4	DELAWARE	21.2	Champaign-Urbana, IL	32.0
ZENTRALSCHWEIZ (CH)	36.0	NEW YORK	20.8	San Jose-Sunnyvale-Santa Clara, CA	31.0
LUXEMBOURG (LU)	35.7	TEXAS	18.9	Trenton-Ewing, NJ	30.4
OSTSCHWEIZ (CH)	31.0	MARYLAND	18.2	Albany-Schenectady-Troy, NY	28.5
PROV. BRABANT WALLON (BE)	30.1	CONNECTICUT	17.7	Columbus, IN	28.5
INNER LONDON (UK)	28.0	OREGON	17.4	Lansing-East Lansing, MI	28.3
SOUTHERN AND EASTERN (IE)	22.0	IDAHO	16.4	Athens-Clarke County, GA	28.2
PROV. LUXEMBOURG (BE)	21.5	HAWAII	16.1	Ithaca, NY	28.0
PROV. ANTWERPEN (BE)	19.7	FLORIDA	15.6	Ann Arbor, MI	27.7
OUTER LONDON (UK)	19.4	NEW MEXICO	15.4	Gainesville, FL	27.6
NOORD-BRABANT (NL)	19.3	ARKANSAS	15.1	College Station-Bryan, TX	27.3
ESPACE MITTELLAND (CH)	19.0	ILLINOIS	14.8	New York-Northern New Jersey-Long Island, NY-NJ-PA	24.3
PROV. VLAAMS-BRABANT (BE)	18.8	PENNSYLVANIA	14.6	Santa Barbara-Santa Maria-Goleta, CA	24.0
TICINO (CH)	18.2	GEORGIA	14.3	Ames, IA	23.2
TIROL (AT)	17.8	MICHIGAN	14.2	Dallas-Fort Worth-Arlington, TX	23.1
EAST ANGLIA (UK)	17.4	NORTH CAROLINA	14.1	State College, PA	22.6
PROV. HAINAUT (BE)	17.0	ARIZONA	13.9	Boston-Cambridge-Quincy, MA-NH	22.5
European average	**9.7**	**US average**	**18.5**	**US average**	**18.5**

Note: Only NUTS2 (*Nomenclature des unités territoriales statistiques*) regions with more than 25 native inventors and MSAs with more than 150 native inventors are listed here.

Source: WIPO Statistics Database, October 2013

Table 6: Most populated migration corridors, 2006-10

Largest inventor migration corridors			Largest inventor migration corridors (excluding the US)		
Origin	**Destination**	**Inventors**	**Origin**	**Destination**	**Inventors**
China	United States of America	27,698	Germany	Switzerland	4,949
India	United States of America	21,712	France	Switzerland	1,879
Canada	United States of America	11,363	France	Germany	1,492
United Kingdom	United States of America	8,314	China	Japan	1,462
Germany	United States of America	5,894	Germany	Netherlands	1,332
Germany	Switzerland	4,949	Austria	Germany	1,307
Republic of Korea	United States of America	4,876	France	United Kingdom	1,210
France	United States of America	3,901	China	Singapore	1,149
Japan	United States of America	2,843	Germany	Austria	1,107
Russian Federation	United States of America	2,308	United Kingdom	Germany	1,080
France	Switzerland	1,879	Netherlands	Germany	1,049
Israel	United States of America	1,875	United States of America	China	1,041
Australia	United States of America	1,783	Germany	United Kingdom	969
Netherlands	United States of America	1,670	Italy	Germany	956
Italy	United States of America	1,492	Italy	Switzerland	955
France	Germany	1,492	France	Belgium	934
China	Japan	1,462	Germany	France	916
Germany	Netherlands	1,332	United Kingdom	Switzerland	887
Austria	Germany	1,307	United States of America	Germany	820
Turkey	United States of America	1,233	United States of America	Canada	807

Source: WIPO Statistics Database, October 2013

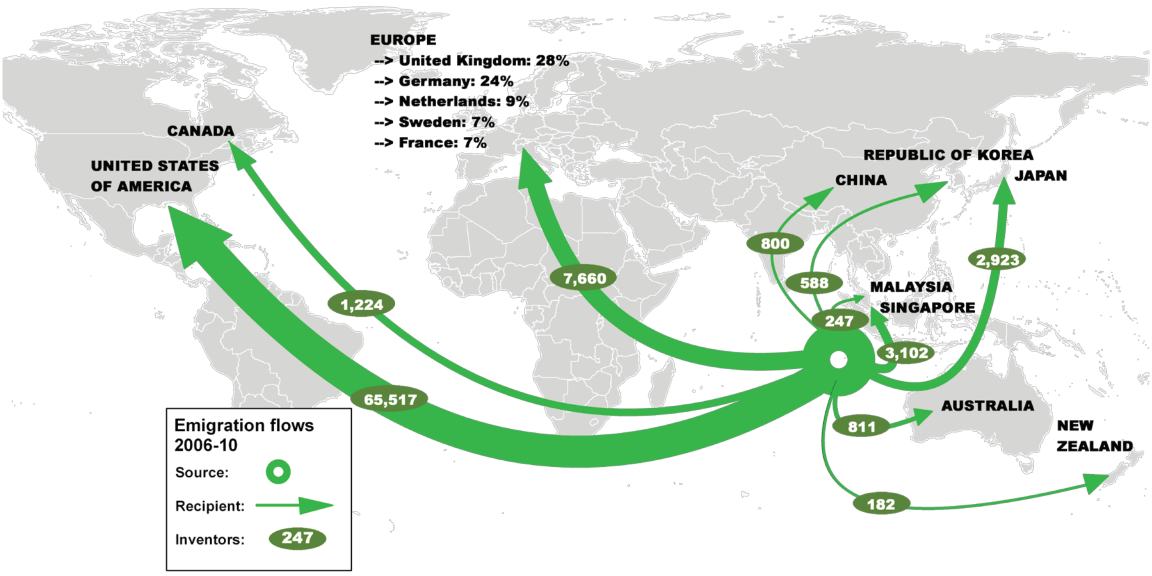
Which are the most popular inventor migration corridors?

Table 6 shows the most populated bilateral corridors during the 2006-10 period. The US emerged as the most frequent destination country. Origin countries belong to the high-income group, except China and India. The top two corridors are China-US (27,698 inventors) and India-US (21,712). In both cases, the high-income country is the destination and the middle-income country is the origin. When the US as a destination country was excluded from the analysis, intra-European flows of inventors dominated the top corridors. There were, however, some interesting exceptions, such as the China-Japan (1,462) corridor and the China-Singapore (1,149) corridor.

Asian countries – and to a lesser extent, countries from Oceania – are important sources of inventors. Figure 5 depicts the top 10 most popular destinations for inventors originating from the Middle East, South Asia, East Asia and Oceania. As can be seen, the proportion of inventors going to the US was greater than that going to other countries. For example, close to nine times as many migrant inventors from these regions as a whole immigrated to the US (65,517) than immigrated to Europe (7,660). They represented 55.9% of all immigrant inventors in the US for the period 2006-10. While China's and India's migration flows to the US were largely responsible for this phenomenon, other countries also played a role. Moreover, countries from the above-mentioned broad geographical region featured among the top 10 destinations for inventors. In particular, Australia, China, Japan, Malaysia, New Zealand, Singapore and the Republic of Korea attracted large numbers of inventors from this collection of geographical regions. In addition, within Europe, the UK received the largest share (28%) of inventors from these regions, followed by Germany (24%).

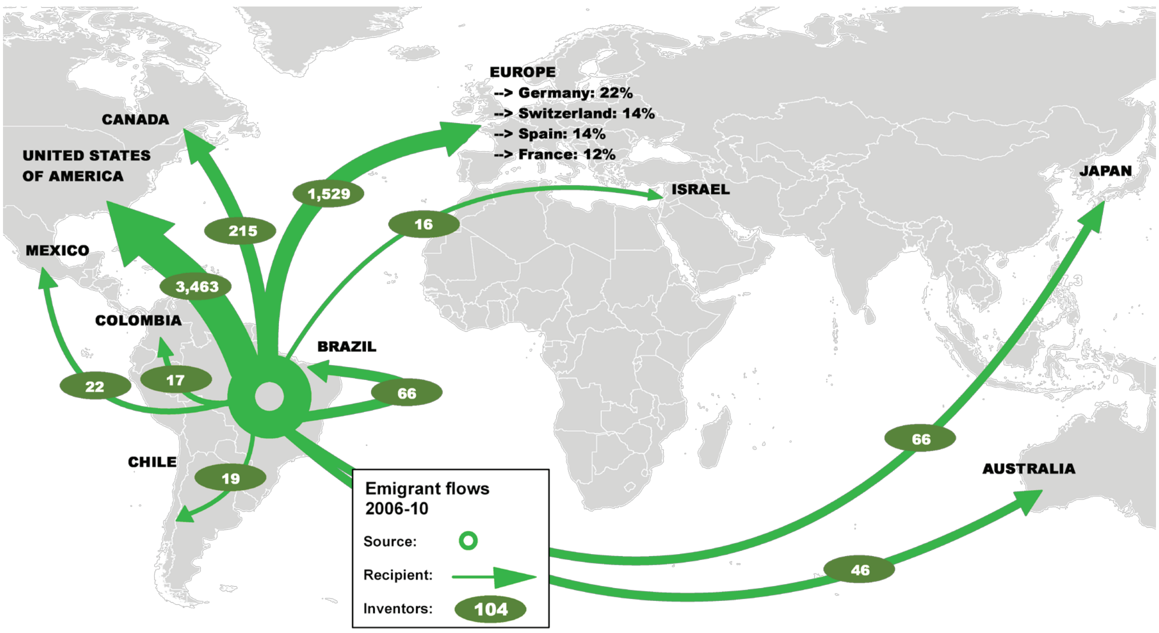
For comparison purposes, Figure 6 depicts the top 10 most popular destinations for inventors from Latin America and the Caribbean (LAC). As Table 1 shows, the absolute number of inventors emigrating from the LAC region was substantially lower when compared with the corresponding figures for Asia. Again, the US topped the ranking of destination countries. In relative terms, LAC inventors accounted for approximately 3% of all immigrants in the US and for approximately 2% of all immigrants in Europe. Within Europe, Germany topped the ranking (22% of all inventor migrants from the LAC region to Europe), and was followed by Switzerland, Spain and France. A shared colonial heritage and a common language explain why Spain attracted considerable talent from LAC countries. The data also show considerable intra-regional mobility of inventors within the LAC region. For example, four LAC countries (Brazil, Chile, Colombia and Mexico) are in the top 10 ranking as destination countries for inventors originating from the LAC region.

Figure 5: Where do inventors from the Middle East, South Asia, East Asia, and Oceania emigrate from?



Source: WIPO Statistics Database, October 2013

Figure 6: Where do LAC inventors emigrate from?



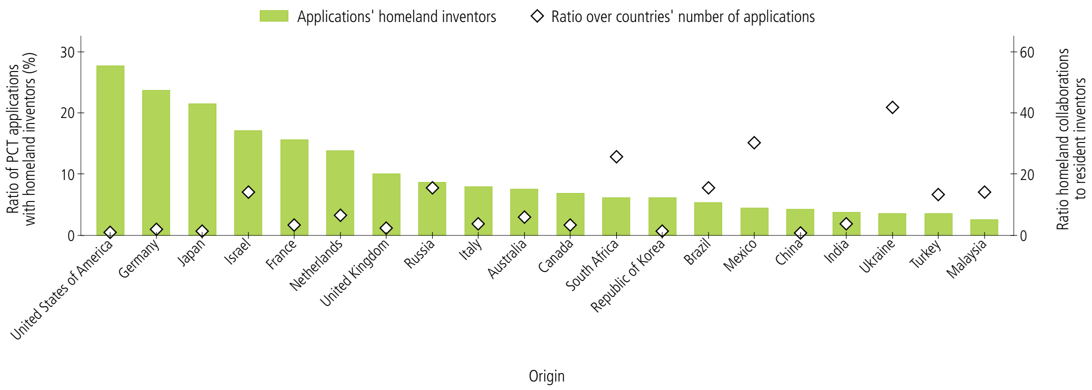
Source: WIPO Statistics Database, October 2013

Do sending countries gain from the brain drain?

Despite the adverse consequences of the brain drain of high-skilled people on a country's potential development, it is also well recognized that emigrants do not necessarily sever their ties with their homelands and, as diasporas, they may constitute a valuable resource in terms of accessing foreign knowledge and technologies. To explore this point further, one can compute the share of patents filed by the emigrant inventors of each country that include at least one inventor residing in the emigrant country of origin. The idea is to analyze the extent to which each country's emigrant inventor community is committed to their country of origin and, as a consequence, the extent of their collaboration with their co-national colleagues at home. As the left axis of Figure 7 shows, the US diaspora seems to be the most committed to their homeland; 27.2% of the PCT applications with US inventor emigrants included US residents among their co-inventors.

However, bearing in mind that the absolute number of US resident inventors accounted for the world's largest number of resident inventors during the 2006-10 timeframe, the probability of collaborating with a US resident inventor was very high, regardless of the commitment of US inventors abroad and the extent of their collaboration with their home country colleagues. In order to illustrate this last point, Figure 7 computes a hypothetical ratio between the share of patents co-invented with nationals of the country of origin and the share of total inventors residing in the country of origin (see black and white diamonds on right axis). The results show that inventors from middle-income countries were actually the most committed to their homelands, in that they collaborated with their national colleagues at home disproportionately more than would have been expected, given their share of total inventors. In fact, the only two countries which had a ratio lower than 1 during this period were China and the US, which indicates that inventors from these countries are less committed to their country of origin than would have been expected, given their share of the total number of inventors.

Figure 7: Share of PCT applications with homeland inventors and its ratio with the share of resident inventors with whom to collaborate: 2006-10



Source: WIPO Statistics Database, October 2013

Conclusion

This special section described a new global dataset on migrant inventors, using information on inventor nationality and residence gleaned from PCT applications. From this analysis, two important facts emerged. First, from a methodological perspective, this section demonstrated that PCT data are meaningful and are useful in analyzing the interplay between migration and innovation. Second, from a more analytical viewpoint, the data reveal a number of interesting findings that are worth highlighting.

From the methodological perspective, use of patent data to map the migratory patterns of high-skilled workers can address some of the limitations associated with existing migration datasets. In particular, this database covers a long time period, provides information on an annual basis, and contains data for a large number of sending and receiving countries. Inventors constitute a group of high-skilled workers of special economic importance who have more homogenous skills than tertiary-educated workers as a whole.

Broadly speaking, the data clearly demonstrate that the pattern of inventors' mobility resembles other high-skilled migration figures, and in particular, what we know about the migration of scientists and engineers based on anecdotal evidence, surveys and media reports. For example, the majority of immigrant inventors in the 2006-10 period were concentrated in the US, whereas European countries lagged behind in this respect. The US not only had the largest absolute number of immigrant inventors during this period, but it also stood out as one of the main receiving countries relative to its total population of inventors.

The data highlight important differences across countries as well as within countries and across different cities, technologies and organizations employing inventors (applicants). In addition, they highlight that during the 2006-10 period, immigration rates were remarkably different across applicant types i.e., university, government and research institutions, business, and individuals. Within these groupings, university/government immigration rates were considerably higher than business sector immigration rates. In relation to data for fields of technology, for example, during the 2006-10 period immigration rates varied from 4.1% (mechanical elements) to 18.3% (micro-structure and nano-technology). Other fields also relied heavily on immigrant inventors; such fields included pharmaceuticals (14.6%), biotechnology (14.6%), digital communication (15.2%) and basic communication processes (16%).

Furthermore, by using unit record data, it becomes possible to link patent-inventor data with citation and co-inventorship information. It also becomes possible to study social relationships between inventors and subsequent knowledge diffusion patterns across countries, regions and technology fields. Additionally, data can also be linked to country-, city- and firm-level information in order to provide new empirical evidence on a broad range of interrelated topics.

From an analytical standpoint, this special section provides new evidence on the migration patterns of knowledge workers which, to date, have probably not received the attention that this subject deserves. As a result, most analysis on the migration patterns of scientists and engineers has exclusively focused on the US experience and its major providers of foreign talent, namely China and India (Breschi *et al*, 2013). However, high-skilled worker migration is a multipolar phenomenon, implying a large number of sending and receiving countries.

Thus, for example, it is possible to observe trends in important talent circulation between Western European countries during the 2006-10 period. It is also possible to observe that the number of non-European countries providing talent to Europe did not necessarily coincide with migration flows to the US – e.g., from African or LAC countries. During this period, European countries also constituted the main providers of talent to the US.

There is large "brain circulation" between Asian economies, with Singapore standing out as a major receiving country. For its part, China is a major provider of talent within its geographical area of influence; however, in recent years, it has also attracted a large number of immigrant inventors, both from Asia and the rest of the world. Finally, albeit to a lesser extent, migrant inventors also originate in other areas of the world, such as LAC countries and Africa.

Of course, using patent data for the purpose of economic analysis does not come without limitations. One important caveat is that one only observes inventors when they seek patent protection. Not all inventions are patented, however, and there is no one-to-one correspondence between the number of patent applications filed and the commercial value of the underlying inventions or their contribution to technological progress. Another limitation is that the PCT dataset does not include inventors with a migratory background who have become a host country national. Unfortunately, the data do not facilitate the assessment of how severe these biases are. In using these data, one should be aware of such 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 section suggests that it is consistent with migratory patterns and trends elicited from census data. At the same time, the database opens up new avenues for research and promises to generate fresh empirical insights that can inform both innovation policy and migration policy.

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