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Immigration barriers and net brain drain

Sultan Orazbayev*

March 31, 2017

Abstract

Education and employment histories of more than 650 thousand scientists contained in ORCID data can shed light on the patterns of brain drain and brain gain in over 200 countries (and territories) over the last 40 years. The incidence of brain drain and brain gain is positively correlated across space and time. More restrictive immigration policy towards skilled workers and students is associated with lower levels of skilled emigration (brain drain), consistent with competition of domestic and foreign scientists for a limited number of domestic academic posts. However, after controlling for time and country heterogeneity, increased barriers to immigration are associated with a relatively larger effect on the inflow of skilled immigrants (brain gain), so more restrictive policy is associated with net brain drain.

Keywords: brain drain; brain gain; high-skilled migration; scientific mobility; immigration policy.

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1 Introduction

Modern science is a complex system with numerous scientists communicating and collaborating across large distances. Stakeholders in this system, such as funding organisations, research institutions and scientists themselves, need an accurate identification of contributors. Open Researcher and Contributor ID (ORCID), a central registry of contributors, was introduced to overcome the author identification problem (Haak et al. 2012). Users voluntarily register on ORCID to obtain a unique code which they can use to identify their contributions. ORCID data can then be used to reduce the reporting burden through automation and offers other benefits (Haak et al. 2012). Currently there are more than 3 million ORCIDs issued, primarily to scientists and researchers in academia and industry. The rest of the paper will refer to ORCID users as researchers, scientists and high-skilled workers interchangeably.

The ORCID user's complete profile includes information on their contributions (e.g. journal publications), education and employment histories.[1] This information is aimed at prospective employers, funding agencies and broader scientific community, but it is also of great interest for researchers interested in the emerging field of "science of science". Until now such detailed data was collected through surveys and CV analysis, both methods are expensive and time-consuming which constrained previous analyses to relatively small samples (Franzoni et al. 2012; Dietz et al. 2000). ORCID provides a standardised, comprehensive source of data on education and employment of scientists, providing opportunities for large-scale

[1]Not every user provides complete information, the data used in this paper includes profiles of approximately 650 thousand researchers which provided at least some information about education and/or employment.

analysis of patterns in academic productivity, social networks, agglomeration, diffusion of knowledge, mobility, migration and many other areas.

This paper uses public information provided by 658'204 ORCID users about their education and employment to examine the geography of brain drain, brain gain and brain circulation. Immigration policy towards skilled-workers and students, by design, will seek to regulate entry of skilled workforce, but indirectly it will affect competition for domestic academic positions and hence will also influence emigration of the domestic scientists. What is the net impact of stricter immigration policy? The paper combines information on policies in more than 40 countries over 1990–2014 from DEMIG POLICY dataset (DEMIG 2015) with the brain gain and brain drain imputed from ORCID data to explore the overall impact of immigration policy on net brain gain.

Section 2, provides a brief description of the dataset and the overview of aggregate patterns of brain gain and brain drain. Section 3 explores the relationship between immigration policy and net brain gain. The last section concludes the paper with a discussion of the results.

2 Data sources and aggregate patterns

The analysis in this paper uses two primary data sources — Haak et al. (2016) for estimating brain gain/drain and DEMIG (2015) for data on immigration policy.

2.1 ORCID data

Information on ORCID is taken from the public data set containing information provided by users as of October 1, 2016 (Haak et al. 2016), also available on-

line at `https://orcid.org/content/orcid-public-data-file`. This data was processed to extract information on education and employment histories of ORCID users. The descriptions of education were used to identify undergraduate, postgraduate and PhD education through a semi-manual process of identifying frequently occurring titles and using them to classify education episodes.

To analyse the incidence of brain gain, immigration of foreign scientists, and brain drain, emigration of domestic scientists, we need information on a scientist's origin. In cases of highly-mobile individuals, it is difficult to define one specific 'origin', so the existing literature uses various proxies such as country of birth, country of residence at the age of 18, or country of undergraduate education (Hunter et al. 2009; Franzoni et al. 2012; Fernandez-Zubieta et al. 2015). ORCID profiles do not contain information on author's nationality, citizenship or country of birth. As a result, it's not possible to identify the scientist's exact 'origin' country, however the origin country can be approximated using several approaches. The information presented in this paper uses the country of the scientist's first place of education or employment (whichever is earliest). The drawback of this approach is that it will underestimate brain drain by not taking into account mobility of individuals prior to education/employment, but approaches based on the country of undergraduate education or place of first employment give similar results. Orazbayev (2017b) conducts several validation exercises to show that ORCID-based data compares well with external sources of micro- and macro-level data. For example, information on country of birth was extracted from ORCID users with a Wikipedia page with 76% match rate between country of birth and country of first education or employment for 460 users that had both a Wikipedia page and an ORCID profile with public details on education and/or employment history.

ORCID user base is growing quickly (Figure 1b) and represents almost every country in the world, both by current location (Figure 1c) and by the imputed origin (Figure 1d). The dates of attendance can be used to calculate the length of PhD programs (Figure 1a), which has stayed approximately constant over the sample period at about 4–5 years.[2]

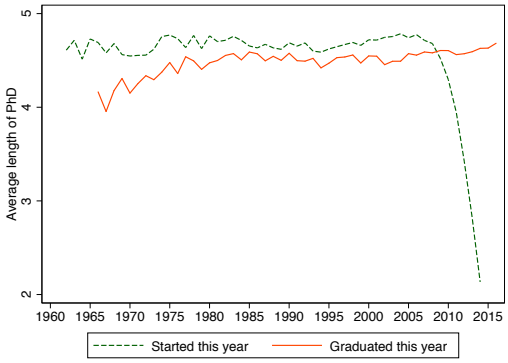
2.2 DEMIG data

Information on immigration policy is taken from DEMIG POLICY dataset (DEMIG 2015). The dataset contains information on more than 6500 policies in 45 countries. Every policy is categorised depending on the target group (skilled workers, students, low skilled workers, asylum seekers and others), magnitude (e.g. a major change in policy vs. fine-tuning) and direction (increasing restrictiveness or decreasing restrictiveness). This information is used to construct a country-specific index of administrative barriers towards skilled workers and students using methodology described in Orazbayev (2017a). The index of immigration barriers is set to zero in 1990 and is increased (decreased) for every implementation of a restrictive (less restrictive) policy, with the following weights used: fine-tuning (0.1), minor change (0.25), mid-level change (0.5), major change (1). The policy frequency is not uniform across countries, the countries with the largest number of changes in policy towards skilled workers and students over 1990–2014 are: Canada

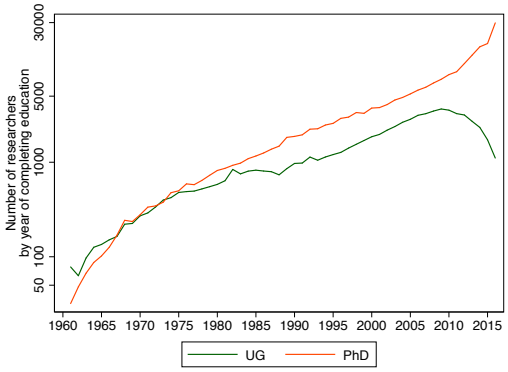
[2]The decline in mean length of a PhD degree towards the end of the sample can be explained by a selection effect (for example, those that enrolled in 2010 and graduated quickly are more likely to be scientifically productive and hence are more likely to register for an ORCID) and a sampling cut-off (e.g. it's not possible to observe in 2016 data of those that enrolled in 2010 but will graduate in 4.5–5 years), but in some cases could also be explained by changes in structure of PhD programs (e.g. MPhil as a pre-cursor to PhD in UK), so selected users could attribute PhD studies only to the last stage of a multi-stage program. Note that these calculations do not include users who chose to enter the same starting and completing year (possibly for convenience) or entered only the date of starting/completing the program.

Figure 1: Selected patterns in ORCID data.

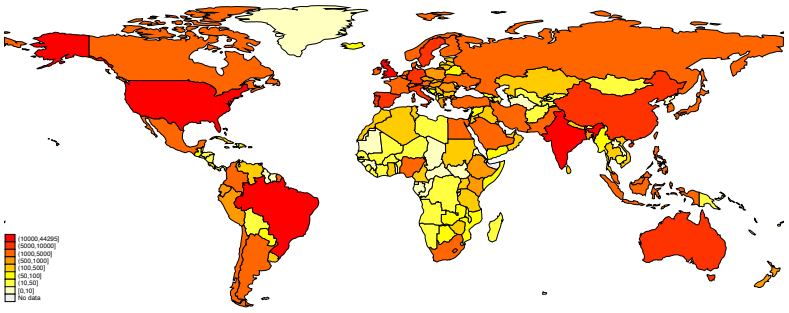
(a) Mean length of a PhD degree.



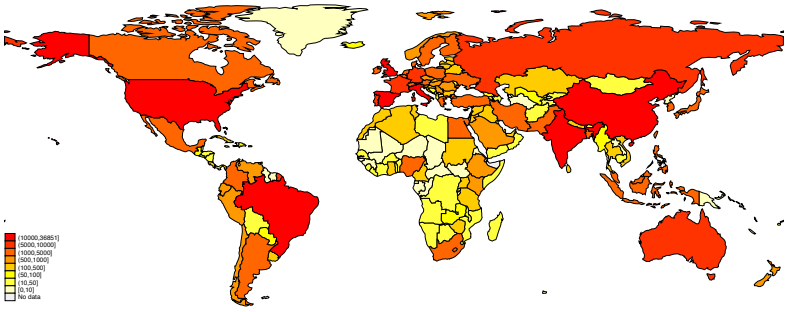
(b) Researchers by year.



(c) Researchers by country of employment in 2015.



(d) Researchers by imputed origin in 2015.



Note: panel (a) see text regarding the decline in mean length of a PhD degree towards the end of the sample; panel (d) defines a scientist's origin to be the country of the scientist's first place of education or employment (whichever is earliest); maps are drawn using spmap (Pisati 2008).

(26), UK (26), USA (25), New Zealand (24), Japan (21), Ireland (21), Australia (20), France (18), Germany (16), Switzerland (12), Slovakia (11), Netherlands (10) and Norway (10). The remaining countries have fewer than 10 policies each.

By design, the index of immigration barriers is country-specific, so it's not possible to perform a cross-sectional comparison using the index. However, the index can be used to examine changes in restrictiveness of immigration policy within a country over time. The broad trend across countries has been to reduce the immigration barriers towards skilled workers and students, see Figure 4.

2.3 Aggregate patterns

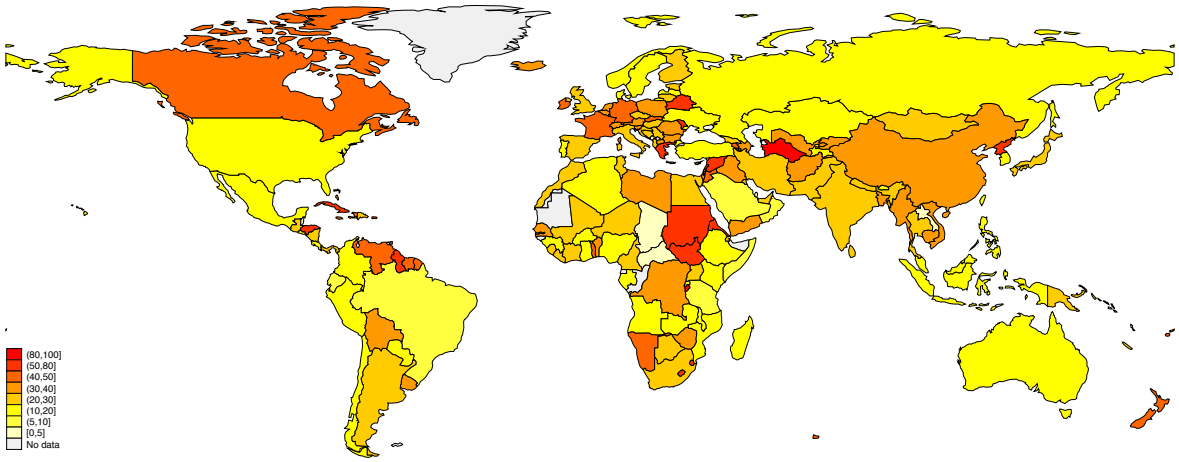
Once a scientist's (most likely) origin is identified, it becomes possible to calculate the incidence of skilled emigration (brain drain) and skilled immigration (brain gain) around the world, Figure 2 shows the data for 2015. Brain drain affects not just the least developed countries (Figure 2a), but also developed economies. However, countries with high brain drain also tend to experience significant brain gain (Figure 2b).

This turnover in skilled workers is known as brain circulation, and evidence of global brain circulation has already been observed through GlobSci survey (Franzoni et al. 2012; Stephan et al. 2016), which used information on approximately 17 thousand respondents to analyse mobility patterns in 16 countries. ORCID data shows that brain circulation is a global phenomenon. To check whether mobility patterns in ORCID data are similar to GlobSci, Table 1 from Franzoni et al. (2012) was re-calculated with ORCID data and updated to 2015, see Table 1.[3]

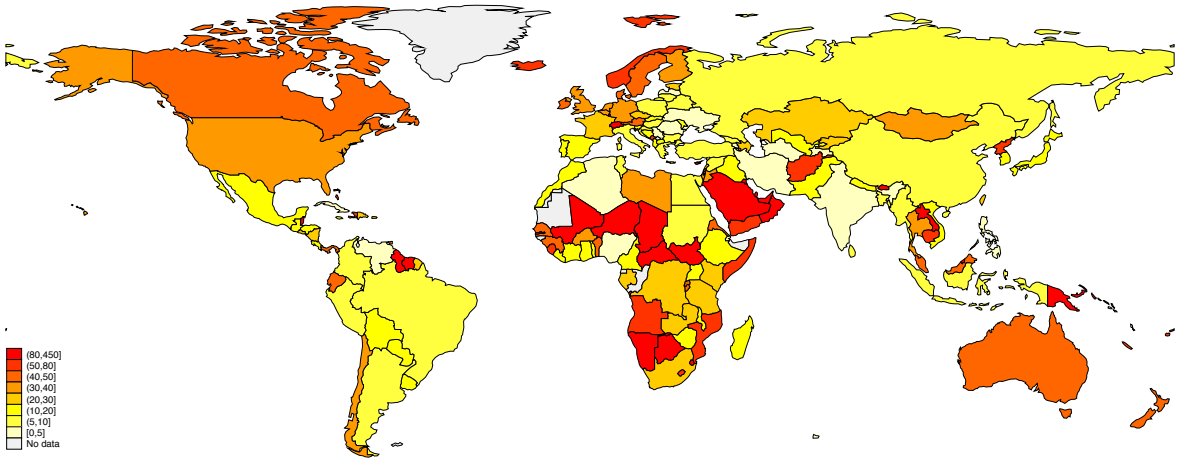
[3]The results for 2010, which corresponds to GlobSci time period, are broadly consistent with Franzoni et al. (2012), see Orazbayev (2017b) for further details.

Figure 2: The geography of brain drain and brain gain in 2015.

(a) Emigration rate of scientists by origin country.



(b) Foreign scientists as % of destination scientists.



Note: the origin of a scientist is defined to be the country of the scientist's first place of education or employment (whichever is earliest); maps are drawn using spmap (Pisati 2008).

Table 1: Mobility patterns for selected countries in 2015.

(a) Statistics by destination countries.

Country of residence in 2015 (# of observations)	% of immigrants	Concentration rate	Popular origins
Australia (11663)	29.9	50.0	UK (21.5), US (13.5)
Belgium (2136)	29.4	37.0	France (10.2)
Brazil (19438)	4.7	52.3	US (21.5), UK (12.4), Portugal (10.3)
Canada (6475)	34.1	51.0	US (28.0)
Denmark (4529)	27.1	35.2	Germany (10.5)
France (7532)	22.0	38.3	Italy (12.3)
Germany (8363)	30.4	33.6	US (10.9)
India (17012)	2.3	64.8	US (39.8), UK (13.8)
Italy (16767)	7.3	47.8	US (18.8), UK (12.7)
Japan (5417)	14.4	49.3	US (19.7), China (15.0)
Netherlands (3825)	26.8	37.8	UK (12.0), US (10.0)
Spain (19760)	9.2	38.2	Italy (11.2), US (10.3), UK (10.1)
Sweden (7433)	24.9	31.5	
Switzerland (2921)	53.9	51.9	Germany (17.7), Italy (11.9), France (11.3), US (11.1)
United Kingdom (23841)	27.4	32.5	US (12.4)
United States (64006)	21.9	46.2	China (20.3), India (11.3)
China (14058)	8.8	55.6	US (29.4), UK (12.2)
Iran, Islamic Republic of (4183)	7.5	56.4	UK (23.6), US (12.7), Malaysia (10.5)
Portugal (12370)	10.8	49.0	Spain (18.2), UK (13.6), Brazil (10.0)
Russian Federation (10971)	3.6	53.6	Ukraine (36.6)

(b) Statistics by origin countries.

Country of origin (# of observations)	% abroad in 2015	% with migration experience	Rate of return migration	Popular destinations
Australia (9580)	14.7	27.5	46.6	UK (20.2), US (19.4)
Belgium (2191)	31.1	44.4	29.8	US (13.6), UK (11.7), France (10.4)
Brazil (19480)	4.9	15.7	68.5	US (29.8), Portugal (13.9)
Canada (6598)	35.4	47.6	25.7	US (43.1), UK (10.6)
Denmark (3696)	10.7	22.7	52.8	US (21.2), Sweden (16.2), UK (12.4)
France (8572)	31.5	44.2	28.8	US (15.4), UK (10.7)
Germany (8919)	34.7	48.7	28.6	US (18.4), UK (12.9)
India (20758)	19.9	26.8	25.6	US (38.3)
Italy (18274)	15.0	27.5	45.4	UK (18.9), US (15.3)
Japan (5758)	19.5	31.0	37.2	US (24.9), Korea, Republic of (10.5)
Netherlands (4019)	30.4	42.5	28.6	UK (18.8), US (14.7)
Spain (20485)	12.4	23.7	47.4	UK (15.7), US (14.7)
Sweden (6294)	11.3	22.2	49.2	US (17.4), Denmark (12.5), UK (10.4)
Switzerland (2035)	33.8	50.2	32.8	US (20.2), UK (12.8), Germany (10.3)
United Kingdom (23556)	26.5	35.6	25.5	US (16.8), Australia (12.0)
United States (58179)	14.1	19.0	25.9	
China (17921)	28.5	44.0	35.2	US (55.7)
Iran, Islamic Republic of (4766)	18.8	29.6	36.4	US (28.7), Canada (9.9)
Portugal (12054)	8.5	27.2	68.8	UK (19.5), US (12.4)
Russian Federation (12028)	12.1	15.5	22.1	US (20.1)

Notes: this table calculates statistics comparable to Table 1 in (Franzoni et al. 2012); the origin of a scientist is defined to be the country of the scientist's first place of education or employment (whichever is earliest); scientists employed in a country different from their origin are defined as immigrants (in the destination country); popular origins (destinations) are countries supplying 10+% of foreign workforce (countries where 10+% of origin scientists were employed) with exact share in parentheses; concentration rate is defined as the cumulative share of top four origins; four countries at the bottom are added based on the size of their scientific communities; migration experience is defined as observation of studying or working for at least one year in a country different from the imputed country of origin; rate of return migration is calculated as the ratio of origin scientists that have international experience and were employed in the origin country in 2010 to the total number of origin scientists with international experience employed in 2010 (in any country).

Countries with large scientific communities vary in their diversity as reflected in immigrant share and concentration of popular origins, Table 1a. The share of immigrant scientists at a destination country varies from about 2% in India and 4% in Russia up to 54% in Switzerland (the share of immigrant scientists in some of the smaller countries is as high as 100%, see Table 4 in Appendix). The cumulative share of the top four origins reflects concentration (lack of diversity) of immigrants and it varies from about 32% in UK and Sweden (high diversity) to approximately 65% in India (low diversity). This does not, however, reflect the increasing diversity of incoming and outgoing skilled flows at both the country and global level (Czaika and Orazbayev 2016). As reported in GlobSci, flows between countries are influenced not just by the size of their communities, but also by cultural ties between the countries and their proximity. For example, about 28% of immigrant scientists in Portugal come from Spain and another 10% from Brazil. Unlike the origin countries reported in GlobSci, the frequency and magnitude of immigrants from US and UK is much larger in ORCID data. This indicates a potential bias due to the procedure used to identify a scientist's most likely origin: if a scientist has started their undergraduate studies in the US or UK (two of the most popular student destinations in developed world), then the scientist's origin becomes US or UK, respectively. However, the high overall correlation of ORCID and GlobSci statistics implies that this assumption is a reasonable approximation.

ORCID and GlobSci results are also similar for origin countries, Table 1b. The share of emigrants from a country varies from about 4% in Brazil and 9% in Portugal to 34% in Switzerland and 35% in Canada. In many countries, however, scientists tend to get at least some experience abroad. The share of origin scientists that get at least some international experience (education or employment outside

country of origin) ranges from about 16% in Russia and Brazil to about 50% in Germany and Switzerland. The rate of return migration (among those with experience abroad) varies from 22% in Russia to 69% in Brazil and Portugal.

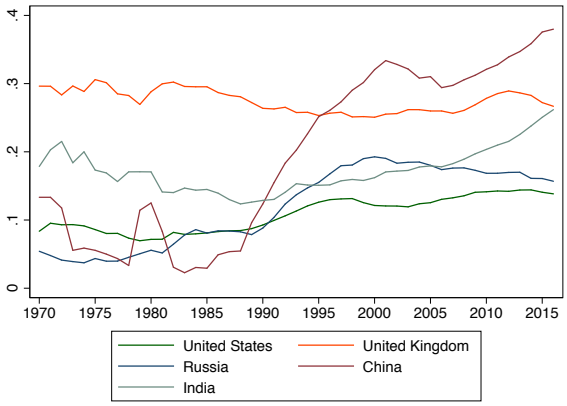
An additional advantage of ORCID data is that it allows examining the mobility patterns over time. Figure 3 documents the patterns of brain drain and brain gain for a selection of countries with large scientific communities. Some of the largest brain drain episodes in history can be seen on Figure 3a — the collapse of the Soviet Union (Borjas and Doran 2012; Ganguli 2015), the rapid drain that started in late 1980s in China (Fangmeng 2016; Freeman and Huang 2015)[4], and the gradual increase in emigration from India.

Another interesting observation is the increase in emigration away from the United States. As mentioned earlier, the assumption used for identifying country of origin generates a potential bias in favour of US and UK, however this is unlikely to be the only explanation since a similar pattern is not observed for UK. Also, the trend in the share of scientists that leave the country of their PhD education (Figure 3b) is relatively stable, suggesting that foreign students that come to US for a PhD tend to remain in US (unlike the pattern in UK). A more likely explanation for the increased emigration rate of US scientists (Figure 3a) is that the influx of foreign scientists and the concomitant increase in competition drove out some of the US scientists. There is evidence of this effect for US mathematicians (Borjas and Doran 2012; Borjas and Doran 2015), so the pattern observed in Figure 3a suggests that this effect applies to other fields of US science as well (also, see Figure 4d for pattern across all countries in 2015).

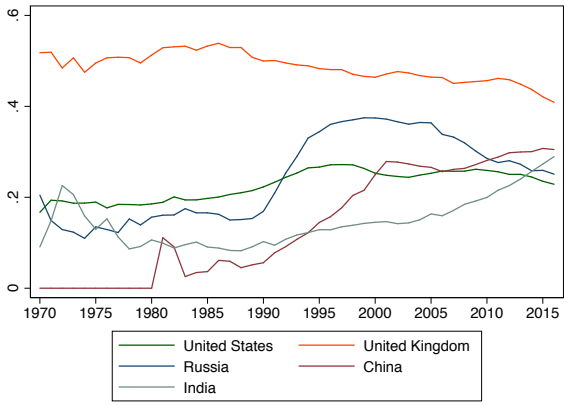
[4]The spike in early 1980 on Figure 3a and Figure 3b capture a special program to send students abroad (Cao 2008).

Figure 3: Dynamics of brain drain and brain gain for selected countries.

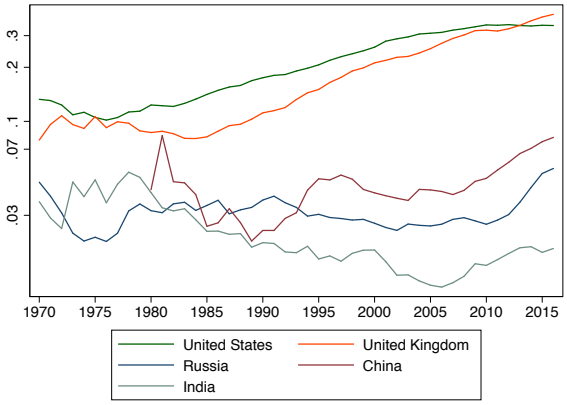
(a) Share of origin scientists that work abroad.



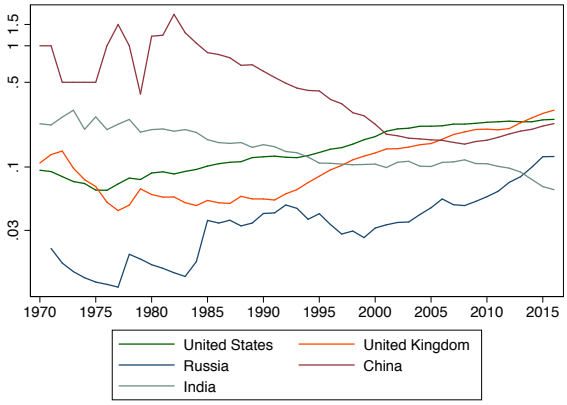
(b) Share of scientists that left the country of PhD education.



(c) Share of immigrant scientists (log scale).



(d) Foreign PhD graduates as % of destination scientists with domestic PhD (log scale).



Notes: vertical axis shows brain drain measured as the fraction of scientists from origin that work abroad (using employment data only); panel (b): vertical axis shows the fraction of scientists that obtained PhD in a given country and relocated abroad; the origin of a scientist is defined to be the country of the scientist's first place of education or employment (whichever is earliest); the vertical axis in panels (c) and (d) uses log scale to make sure that China's dynamics are consistently reflected on both figures, also see Appendix.

Apart from the competitive pressures, brain drain could indicate lack of opportunities and prospects at the origin. Figure 3b shows that India is losing its PhD graduates, while Russia, China, US and UK enjoy some success in retaining PhD students (including foreign students). The data for US closely matches patterns observed in a report of US PhD graduates (Finn 2014), specifically the increasing share of foreign scientists in US and the relatively stable stay rate of US PhD graduates. In case of Russia and China, the stability in retaining own PhD graduates could be explained by the increase in domestic funding and opportunities (Zweig 2006).

Figure 3c shows that UK and US have the highest immigrant scientist shares, and although China has been growing at a faster pace in the last 10 years, its scientific community is still quite homogenous. Figure 3d shows that China enjoys an influx of foreign PhD graduates, but combined with Figure 3c, it means that most of these foreign PhDs are Chinese scientists that return after studying abroad. In 2015 about 8% of scientists in China are estimated to have been foreigners compared to 22% in US and 27% in UK.

As seen on Figure 3d, China's experience especially large increase of own citizens with foreign PhDs in the 1980s. During that period, the government pursued a policy of sending students abroad, while many did not return (Cao 2008) the relative number of those that did was quite large, at least relative to Chinese PhDs that are part of the ORCID sample (i.e. those that remain active in research) .

Figure 3 contains a potentially worrying outlook for India: although the number of foreign scientists in India has increased in the last 10 years, their share is lower than that of peers, such as China, Russia and Brazil (not shown). Moreover, the inflow of foreign PhDs into India is decreasing, which could partly reflect changing

career trajectories (opting for a postdoc abroad instead of getting PhD abroad) or stricter immigration policies in traditional destinations (Czaika and Toma 2015).

The very recent dynamics of brain gain for Russia show increase in immigrant scientists and increase in foreign PhDs, but it remains to be seen whether these increases will persist in light of economic and political developments (Dezhina 2015).

3 Immigration policy and brain gain/drain

The discussion in the previous section shows that a great deal of brain circulation is (and has been) taking place in all of the leading scientific producers. High-skilled immigrants are often expected to have a positive effect on the destination economy, so policy-makers in many countries design immigration policies to attract high-skilled foreigners. However, increased inflow of foreign scientists is likely to lead to increased competition for the relatively fixed number of academic and research positions. Hence it might be the case that a more open immigration policy does not necessarily lead to a net brain gain, as reflected in the difference between incoming foreign and outgoing domestic scientists. Specifically, it's possible that incoming scientists displace the domestic scientists, increasing the country's brain drain.

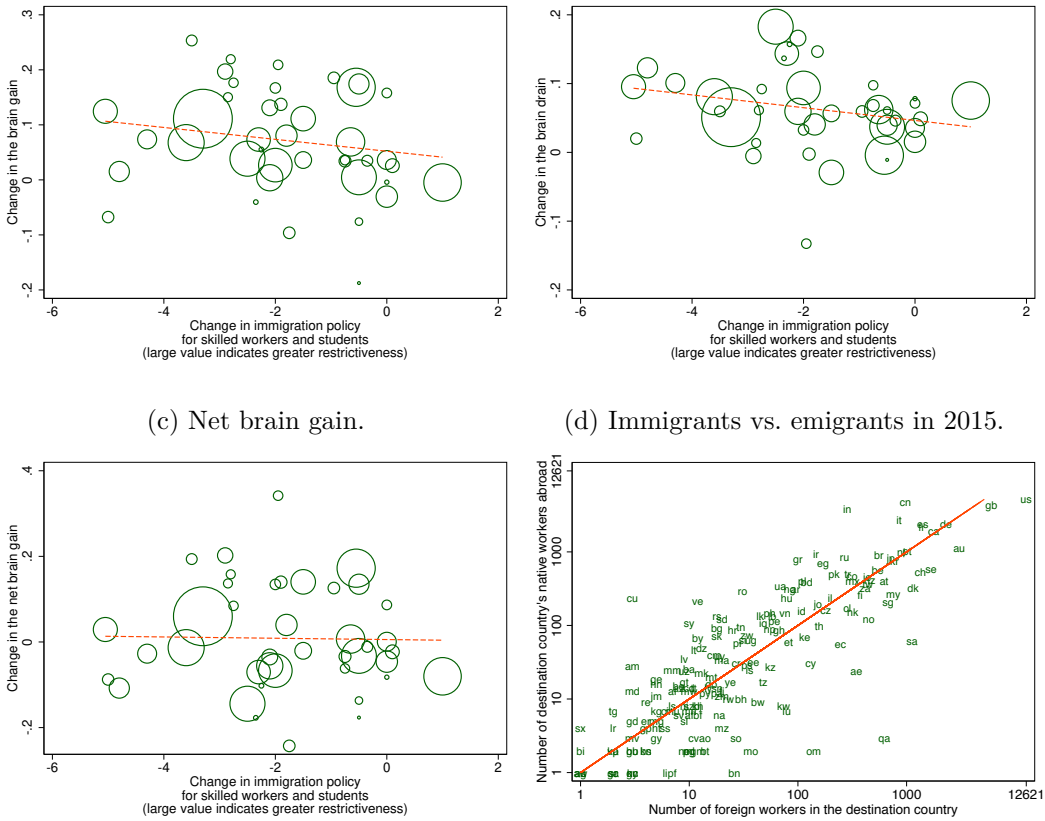
Figure 4 combines ORCID data with information on immigration policies towards skilled workers and students (DEMIG 2015) to check whether countries that became more open over 1990–2014 (relative to themselves) also tend to experience an increase in brain drain, brain gain or net brain gain (relative to each country's value in 1990). This is a purely descriptive comparison and no causal link can be

established from this comparison (Fernandez-Zubieta et al. 2015). Countries that reduced immigration barriers appear to have experienced slightly larger inflow of immigrant scientists (as would be expected), but also they tend to experience an increase in brain drain. Figure 4c shows near-zero correlation between immigration policy and net brain gain over the sample period.

Figure 4: Immigration policy and brain circulation over 1990–2014.

(a) Brain gain.

(b) Brain drain.



(c) Net brain gain.

(d) Immigrants vs. emigrants in 2015.

Note: the vertical axis shows change in a measure of brain drain, gain or net gain (calculated as the difference between brain gain and drain) over 1990–2014; to calculate brain drain/gain the origin of a scientist is defined to be the country of the scientist's first place of education or employment (whichever is earliest); change in immigration policy reflects change in an index of immigration barriers towards skilled workers and students; the size of the bubble corresponds to the size of scientific community (including immigrant scientists).

A more formal examination of the relationship between immigration policy and brain gain/drain must control for country- and time-specific heterogeneity. Assuming that the changes in the index of immigration barriers are comparable across countries, country fixed effect should absorb the country-specific initial value of the index. The following specification will be used:

$$Y_{i,t} = \beta B_{i,t} + \gamma_i + \delta_t + \epsilon_{i,t}, \tag{1}$$

where the dependent variable, $Y_{i,t}$, is a measure of brain gain, drain or net brain gain, $B_{i,t}$ is the country-specific index of immigration barriers for skilled workers and students, γ_i and δ_t are country and time fixed effects, and $\epsilon_{i,t}$ is an error term. The dependent variables are defined as follows: brain gain is calculated as the stock of foreign scientists as share of origin scientists, brain drain is calculated as the share of origin scientists that are outside their origin country, and net gain is calculated as the difference between brain gain and brain drain.

Table 2a shows β, the estimated coefficient of the index of immigration barriers towards skilled workers and students. Increased barriers to immigration are associated with reduced brain gain (the share of immigrant scientists relative to origin scientists) and brain drain (the share of origin scientists that are outside the origin country). The absolute magnitude of the effect on brain gain is larger (than on brain drain), so that higher immigration barriers are associated with a net brain drain (negative brain gain).[5] This result, however, does not necessarily indicate a causal relationship.

One possible test of a causal relationship between the immigration policy and

[5]See Table 3 in the Appendix, which shows that the results are robust to excluding countries with fewer than 10 policies over the sample period.

Table 2: The effect of immigration policy on brain gain, drain and net gain.

(a) All countries (except Luxembourg and Switzerland).

	Gain	Drain	Net gain
Immigration barriers	-0.025	-0.006	-0.019
	(0.008)***	(0.003)**	(0.009)**
R^2	0.39	0.36	0.05
N	1,000	1,000	1,000

(b) Leading values of policy.

	Gain	Drain	Net gain
Immigration barriers	-0.016	0.001	-0.017
	(0.006)**	(0.003)	(0.008)**
Policy in T+1	-0.003	-0.001	-0.002
	(0.003)	(0.001)	(0.003)
Policy in T+2	-0.008	-0.005	-0.003
	(0.006)	(0.003)	(0.007)
R^2	0.35	0.28	0.05
N	920	920	920

(c) Lagged values of policy.

	Gain	Drain	Net gain
Immigration barriers	-0.011	-0.007	-0.004
	(0.006)*	(0.004)*	(0.008)
Policy in T-1	-0.001	-0.000	-0.001
	(0.002)	(0.002)	(0.003)
Policy in T-2	-0.016	0.002	-0.019
	(0.006)**	(0.003)	(0.008)**
R^2	0.39	0.36	0.06
N	920	920	920

Notes: *** (p<0.01), ** (p<0.05), * (p<0.1); all specifications include year and country fixed effects; estimation is performed using 'xtreg, fe vce(robust)' with heteroskedasticity-robust standard errors given in parentheses; the dependent variables are values of brain gain (stock of foreign scientists as share of origin scientists), brain drain (share of origin scientists that are outside their origin country) and net gain (brain gain minus brain drain); the independent variable is the index of immigration barriers for skilled workers and students (higher value indicates more restrictive immigration policy); Luxembourg and Switzerland are excluded due to very high values of brain gain (including these countries in the sampe does not change the qualitative conclusions).

brain gain/drain/net gain is a placebo test based on future values of the immigration policy. It is possible in principle that immigration policy changes are anticipated, so that location decisions of individuals are made today in anticipation of future policy. If this effect is negligible and there's a causal relationship between current immigration policy and brain gain/drain today, then future values of the policy are expected to be insignificant. Table 2b shows that leading values of the immigration barriers are not significant, which is consistent with a causal interpretation of the link from immigration to brain gain.

To examine the persistency of policy Table 2c includes lagged values of immigration policy. The results show that immigration policy continues to matter for brain gain and net brain gain for at least two years.

The results suggest that if a country implements a major restrictive (less restrictive) immigration policy, then inflow of skilled foreigners will decrease (increase) by about 2.5% and the outflow of domestic scientists will decrease (increase) by 0.6%, with the net drain (gain) effect of almost 2% (of all domestic scientists).

4 Conclusion

The results in the previous section suggest that higher immigration barriers are associated with a net brain drain. This analysis, however, does not address the effects of immigration barriers that go beyond simple measures of brain gain and brain drain. Specifically, these measures do not capture changes in allocative efficiency due to rational, optimising scientists being able to find opportunities (at home or abroad) for the best application of their skills. The emerging body of evidence on the causal impact of immigration policy (including travel visa re-

quirements) on high-skilled mobility and diffusion of knowledge (Orazbayev 2017a; Czaika and Orazbayev 2016; Czaika and Haas 2016; Appelt et al. 2015) suggests that a more open economy is likely to benefit from the increase in allocative efficiency by keeping the most competitive scientists (out of foreign and domestic candidates).

There is also some tentative evidence that brain circulation could have a positive, albeit weak by some estimates, effect on quantity or quality of scientific output (Borjas and Doran 2012; Moser et al. 2014; Fernandez-Zubieta et al. 2015), cf. Ali et al. (2007), Hunter et al. (2009), and Borjas and Doran (2015). However, further research is needed to assess the associated costs and to evaluate the net impact of brain circulation on science, origin/destination economies and global welfare, including the role of migration policy (Saxenian 2005; Beine et al. 2008; Stark 2004; Kerr et al. 2016).

The research presented in this paper also shows a positive externality of maintaining an accurate public registry of research-active scientists (Haak et al. 2012). Recognition of this additional contribution to the research community will hopefully provide an additional incentive to register for and complete an ORCID profile, by researchers and institutions. The rich data creates exciting opportunities for future micro- and macro-level research. Future work could also combine ORCID data with CV, survey and bibliometric data to examine new hypotheses about the science of science.

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Appendix

Table 3: The effect of immigration policy on brain gain, drain and net gain (countries with more than 10 policy changes).

	Gain	Drain	Net gain
Immigration barriers	-0.024	-0.006	-0.019
	(0.007)***	(0.003)**	(0.008)**
R^2	0.40	0.36	0.06
N	850	850	850

Notes: *** (p<0.01), ** (p<0.05), * (p<0.1); all specifications include year and country fixed effects; estimation is performed using 'xtreg, fe vce(robust)' with heteroskedasticity-robust standard errors given in parentheses; the dependent variables are values of brain gain (stock of foreign scientists as share of origin scientists), brain drain (share of origin scientists that are outside their origin country) and net gain (brain gain minus brain drain); the independent variable is the index of immigration barriers for skilled workers and students (higher value indicates more restrictive immigration policy); Luxembourg and Switzerland are excluded due to very high values of brain gain (including these countries in the sample does not change the qualitative conclusions).

Table 4: Mobility patterns for all destinations in 2015.

Country of residence (# of observations)	% of immigrants	Concentration rate	Popular origins
Afghanistan (24)	41.7	70.0	Pakistan (30.0), US (20.0), Canada (10.0), Iran, Islamic Republic of (10.0), Thailand (10.0), India (10.0)
Albania (86)	10.5	77.8	Italy (33.3), Turkey (22.2), Croatia (11.1), Serbia (11.1), US (11.1), Czech Republic (11.1)
Algeria (621)	8.7	75.9	France (46.3), UK (16.7)
American Samoa (2)	50.0	100.0	US (100.0)
Andorra (15)	33.3	100.0	Spain (60.0), France (20.0), US (20.0)
Angola (44)	38.6	88.2	Portugal (64.7), Cuba (11.8)
Anguilla (1)	100.0	100.0	India (100.0)
Antarctica (1)	100.0	100.0	US (100.0)
Antigua and Barbuda (2)	50.0	100.0	India (100.0)
Argentina (1686)	7.5	54.0	US (19.0), Spain (16.7)
Armenia (68)	7.4	100.0	Russian Federation (40.0), Georgia (20.0), Germany (20.0), Egypt (20.0)
Aruba (3)	66.7	100.0	India (50.0), US (50.0)
Australia (11663)	29.9	50.0	UK (21.5), US (13.5)
Austria (2089)	35.0	48.7	Germany (28.3)
Azerbaijan (79)	20.3	75.0	Russian Federation (50.0), Iran, Islamic Republic of (12.5)
Bahamas (10)	50.0	100.0	Canada (40.0), US (40.0), UK (20.0)
Bahrain (71)	66.2	57.4	India (21.3), UK (19.1)
Bangladesh (1265)	12.3	52.9	UK (18.7), Japan (14.8), India (11.0)
Barbados (18)	44.4	100.0	UK (50.0), Jamaica (25.0), Canada (12.5), US (12.5)
Belarus (140)	10.0	100.0	Russian Federation (71.4), Ukraine (28.6)
Belgium (2136)	29.4	37.0	France (10.2)
Belize (6)	66.7	100.0	US (50.0), Nicaragua (25.0), Cuba (25.0)
Benin (46)	32.6	40.0	France (13.3), Congo, the Democratic Republic of the (13.3)
Bermuda (6)	66.7	100.0	UK (50.0), Canada (25.0), US (25.0)
Bhutan (45)	44.4	95.0	India (60.0), Australia (20.0), Thailand (10.0)
Bolivia, Plurinational State of (77)	20.8	56.2	US (18.8), Brazil (12.5), Sweden (12.5), Spain (12.5), France (12.5)
Bonaire, Sint Eustatius and Saba (1)	100.0	100.0	Åland Islands (100.0)
Bosnia and Herzegovina (127)	11.0	57.1	Turkey (28.6), UK (14.3)
Botswana (108)	53.7	53.4	UK (17.2), South Africa (17.2), Zimbabwe (10.3)
Bouvet Island (1)	0.0	0.0	
Brazil (19438)	4.7	52.3	US (21.5), UK (12.4), Portugal (10.3)
British Indian Ocean Territory (3)	66.7	100.0	Brazil (100.0)
Brunei Darussalam (53)	56.6	56.7	UK (20.0), Australia (13.3), India (13.3), Malaysia (10.0)
Bulgaria (404)	9.4	71.1	Russian Federation (36.8), Germany (18.4)
Burkina Faso (55)	27.3	60.0	France (40.0)
Burundi (2)	50.0	100.0	US (100.0)
Cambodia (35)	40.0	64.3	Philippines (21.4), Taiwan, Province of China (14.3), France (14.3), Thailand (14.3)
Cameroon (187)	15.5	58.6	France (24.1), Nigeria (17.2), UK (10.3)
Canada (6475)	34.1	51.0	US (28.0)
Cape Verde (23)	56.5	84.6	Portugal (53.8), Brazil (15.4)
Cayman Islands (3)	100.0	100.0	US (66.7), China (33.3)
Central African Republic (4)	25.0	100.0	Belgium (100.0)
Chad (9)	66.7	66.7	Italy (16.7), Algeria (16.7), Burkina Faso (16.7), Guinea (16.7), Niger (16.7), Congo, the Democratic Republic of the (16.7)
Chile (1631)	21.8	50.6	Spain (20.5), US (17.7)
China (14058)	8.8	55.6	US (29.4), UK (12.2)
Christmas Island (1)	100.0	100.0	China (100.0)
Colombia (5451)	8.8	52.0	Spain (21.2), US (17.0)
Congo (6)	66.7	100.0	France (25.0), Kenya (25.0), UK (25.0), Zambia (25.0)
Congo, the Democratic Republic of the (65)	24.6	62.5	Belgium (37.5), Kenya (12.5)
Cook Islands (1)	0.0	0.0	
Costa Rica (303)	15.2	63.0	US (37.0), Germany (10.9)
Croatia (521)	6.1	43.8	US (15.6)
Cuba (408)	2.0	75.0	Russian Federation (37.5), Peru (12.5), Canada (12.5), Slovakia (12.5), Ukraine (12.5), Spain (12.5)
Curaçao (3)	100.0	100.0	Netherlands (33.3), US (33.3), Nepal (33.3)
Cyprus (311)	68.8	86.9	Greece (36.4), UK (22.0), US (21.0)
Czech Republic (1348)	15.4	38.9	Slovakia (14.9)
Côte d'Ivoire (56)	19.6	72.7	France (45.5)
Denmark (4529)	27.1	35.2	Germany (10.5)
Djibouti (4)	0.0	0.0	
Dominica (1)	0.0	0.0	
Dominican Republic (80)	23.8	78.9	Spain (31.6), US (21.1), Cuba (15.8), Venezuela, Bolivarian Republic of (10.5)
Ecuador (1027)	26.0	61.0	Spain (24.0), Cuba (21.7)
Egypt (3789)	6.6	57.4	US (18.1), UK (17.7), Germany (10.8), Canada (10.8), Japan (10.4)

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Country of residence (# of observations)	% of immigrants	Concentration rate	Popular origins
El Salvador (59)	22.0	61.5	US (23.1), Cuba (15.4), Costa Rica (15.4)
Eritrea (12)	50.0	100.0	India (66.7), Italy (16.7), UK (16.7)
Estonia (222)	21.6	41.7	Russian Federation (20.8)
Ethiopia (798)	12.8	55.9	India (36.3)
Falkland Islands (Malvinas) (1)	100.0	100.0	France (100.0)
Faroe Islands (8)	62.5	100.0	Denmark (60.0), UK (20.0), Serbia (20.0)
Fiji (41)	51.2	57.1	India (28.6)
Finland (1890)	23.8	32.7	
France (7532)	22.0	38.3	Italy (12.3)
French Guiana (9)	55.6	100.0	France (80.0), US (20.0)
French Polynesia (16)	56.2	100.0	France (88.9), US (11.1)
French Southern Territories (1)	0.0	0.0	
Gabon (12)	33.3	100.0	Cameroon (25.0), Morocco (25.0), France (25.0), UK (25.0)
Gambia (27)	44.4	83.3	Nigeria (41.7), India (16.7), UK (16.7)
Georgia (103)	11.7	100.0	Russian Federation (58.3), US (25.0)
Germany (8363)	30.4	33.6	US (10.9)
Ghana (657)	12.0	54.4	UK (30.4), US (10.1)
Gibraltar (2)	50.0	100.0	Italy (100.0)
Greece (1357)	14.1	75.5	UK (44.3), US (19.3)
Greenland (6)	100.0	100.0	Denmark (50.0), Hungary (16.7), UK (16.7), China (16.7)
Grenada (9)	55.6	100.0	US (40.0), Belgium (20.0), Greece (20.0), Trinidad and Tobago (20.0)
Guadeloupe (11)	45.5	100.0	France (80.0), Portugal (20.0)
Guam (8)	37.5	100.0	US (66.7), Spain (33.3)
Guatemala (74)	20.3	73.3	Spain (26.7), Mexico (20.0), US (20.0)
Guinea (10)	30.0	100.0	Belgium (66.7), Italy (33.3)
Guinea-Bissau (2)	100.0	100.0	Denmark (50.0), Portugal (50.0)
Guyana (8)	87.5	100.0	India (57.1), US (28.6), Ukraine (14.3)
Haiti (10)	40.0	100.0	France (50.0), US (25.0), Cuba (25.0)
Holy See (Vatican City State) (2)	100.0	100.0	Italy (50.0), France (50.0)
Honduras (31)	19.4	83.3	Cuba (33.3), Spain (16.7), Brazil (16.7), UK (16.7), US (16.7)
Hong Kong (704)	52.6	78.6	China (42.2), US (19.7), UK (11.6)
Hungary (1310)	8.0	38.1	Romania (13.3)
Iceland (155)	41.3	65.6	US (26.6), UK (14.1), Denmark (14.1), Sweden (10.9)
India (17012)	2.3	64.8	US (39.8), UK (13.8)
Indonesia (2991)	5.4	57.7	Japan (17.8), US (16.0), Australia (15.3)
Iran, Islamic Republic of (4183)	7.5	56.4	UK (23.6), US (12.7), Malaysia (10.5)
Iraq (641)	9.4	75.0	UK (50.0), Malaysia (15.0)
Ireland (1464)	38.5	51.0	UK (31.1)
Isle of Man (5)	40.0	100.0	Italy (100.0)
Israel (942)	31.6	63.1	US (30.5), India (13.4), Russian Federation (11.7)
Italy (16767)	7.3	47.8	US (18.8), UK (12.7)
Jamaica (38)	28.9	63.6	US (36.4)
Japan (5417)	14.4	49.3	US (19.7), China (15.0)
Jersey (3)	33.3	100.0	Egypt (100.0)
Jordan (608)	42.3	61.5	US (29.2), UK (19.8)
Kazakhstan (344)	20.3	61.4	Russian Federation (37.1), US (12.9)
Kenya (878)	18.2	53.1	UK (20.0), US (18.8)
Kiribati (1)	100.0	100.0	Fiji (100.0)
Korea, Democratic People's Republic of (3)	66.7	100.0	Norway (50.0), Finland (50.0)
Korea, Republic of (7286)	17.5	80.6	US (54.3), India (13.1)
Kosovo? (1)	100.0	100.0	Albania (100.0)
Kuwait (185)	62.7	62.9	US (28.4), Egypt (12.9), UK (12.1)
Kyrgyzstan (42)	14.3	83.3	Kazakhstan (33.3), India (16.7), Russian Federation (16.7), Turkey (16.7), Hungary (16.7)
Lao People's Democratic Republic (13)	46.2	100.0	Japan (33.3), India (33.3), Philippines (16.7), UK (16.7)
Latvia (265)	6.4	64.7	Russian Federation (35.3), US (11.8), Ukraine (11.8)
Lebanon (255)	37.6	75.0	US (29.2), France (29.2), UK (10.4)
Lesotho (15)	66.7	90.0	UK (30.0), Malawi (20.0), Cameroon (20.0), South Africa (20.0), Kenya (10.0)
Liberia (17)	17.6	100.0	US (66.7), Norway (33.3)
Libya (79)	26.6	61.9	UK (23.8), US (19.0)
Liechtenstein (11)	63.6	100.0	Switzerland (42.9), Austria (28.6), Lebanon (14.3), Portugal (14.3)
Lithuania (302)	6.0	55.6	Russian Federation (22.2), Germany (11.1), Latvia (11.1), Portugal (11.1), US (11.1)
Luxembourg (126)	76.2	59.4	France (20.8), Germany (18.8), Belgium (10.4)
Macao (49)	79.6	66.7	Portugal (23.1), China (23.1), US (12.8)
Macedonia, the Former Yugoslav Republic of (124)	12.9	62.5	Albania (25.0), UK (18.8), Bulgaria (12.5)

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Country of residence (# of observations)	% of immigrants	Concentration rate	Popular origins
Madagascar (38)	15.8	83.3	France (33.3), Germany (16.7), Indonesia (16.7), Belgium (16.7), UK (16.7)
Malawi (121)	12.4	100.0	UK (53.3), South Africa (20.0), Australia (13.3), US (13.3)
Malaysia (3573)	28.9	55.4	UK (25.2), India (13.1), US (11.3)
Maldives (5)	60.0	100.0	Malaysia (33.3), Nepal (33.3), India (33.3)
Mali (28)	42.9	75.0	Morocco (25.0), India (16.7), Ghana (16.7), Senegal (16.7)
Malta (53)	32.1	76.5	UK (35.3), Spain (17.6), Italy (17.6)
Marshall Islands (1)	0.0	0.0	
Martinique (2)	0.0	0.0	
Mauritius (23)	43.5	70.0	India (20.0), France (20.0), UK (20.0), Brazil (10.0), Nigeria (10.0), Madagascar (10.0)
Mayotte (1)	100.0	100.0	Senegal (100.0)
Mexico (4861)	13.3	64.6	US (28.4), Spain (17.9), UK (11.6)
Moldova, Republic of (25)	20.0	100.0	Russian Federation (60.0), Romania (20.0), Italy (20.0)
Monaco (15)	80.0	75.0	France (33.3), Italy (16.7), US (16.7)
Mongolia (57)	22.8	76.9	Korea, Republic of (23.1), US (23.1), Hungary (15.4), Japan (15.4), Russian Federation (15.4)
Montenegro (25)	28.0	100.0	Serbia (71.4), US (14.3), Croatia (14.3)
Morocco (287)	12.9	78.4	France (54.1), Spain (13.5)
Mozambique (97)	25.8	84.0	Portugal (48.0), Brazil (16.0), Australia (12.0)
Myanmar (74)	10.8	62.5	Japan (25.0), Philippines (12.5), Australia (12.5), Spain (12.5), Iran, Islamic Republic of (12.5), India (12.5)
Namibia (41)	58.5	70.8	South Africa (37.5), Zimbabwe (16.7)
Nepal (380)	22.6	55.8	India (30.2), China (11.6)
Netherlands (3825)	26.8	37.8	UK (12.0), US (10.0)
New Caledonia (13)	53.8	100.0	France (100.0)
New Zealand (1575)	38.9	56.5	UK (23.2), US (16.8), Australia (10.3)
Nicaragua (59)	18.6	63.6	Mexico (27.3), Canada (18.2)
Niger (19)	63.2	58.3	Nigeria (33.3)
Nigeria (2530)	4.5	62.6	UK (29.6), US (13.9), India (11.3)
Northern Mariana Islands (1)	100.0	100.0	US (100.0)
Norway (1657)	31.2	39.5	UK (12.4)
Oman (244)	69.7	54.1	India (34.7), UK (10.0)
Pakistan (2407)	10.7	59.7	UK (27.1), China (13.6), US (11.2)
Palau (1)	0.0	0.0	
Palestine, State of (147)	44.9	56.1	US (24.2), Jordan (16.7)
Panama (64)	37.5	54.2	US (20.8), UK (12.5), Venezuela, Bolivarian Republic of (12.5)
Papua New Guinea (29)	37.9	72.7	Australia (36.4), UK (18.2)
Paraguay (162)	12.3	70.0	Brazil (30.0), Colombia (15.0), Mexico (15.0), Spain (10.0)
Peru (866)	9.5	59.8	Spain (24.4), US (23.2)
Philippines (1795)	4.2	48.7	US (19.7), Japan (13.2)
Poland (1974)	6.3	44.0	Ukraine (15.2), US (11.2), UK (10.4)
Portugal (12370)	10.8	49.0	Spain (18.2), UK (13.6), Brazil (10.0)
Puerto Rico (162)	34.6	78.6	US (60.7)
Qatar (1010)	73.9	49.9	US (19.2), UK (12.3)
Romania (1431)	3.1	50.0	UK (13.6), France (13.6), Italy (13.6)
Russian Federation (10971)	3.6	53.6	Ukraine (36.6)
Rwanda (100)	30.0	56.7	UK (16.7), India (16.7), Kenya (13.3), US (10.0)
Réunion (21)	19.0	100.0	France (100.0)
Saint Kitts and Nevis (6)	83.3	80.0	India (20.0), Italy (20.0), Barbados (20.0), Poland (20.0), US (20.0)
Saint Lucia (1)	100.0	100.0	India (100.0)
Saint Vincent and the Grenadines (3)	100.0	100.0	Nepal (66.7), US (33.3)
Samoa (2)	50.0	100.0	Australia (100.0)
San Marino (7)	100.0	100.0	Italy (71.4), US (14.3), Spain (14.3)
Sao Tome and Principe (2)	100.0	100.0	Japan (50.0), Brazil (50.0)
Saudi Arabia (2317)	58.0	51.9	Egypt (19.0), India (15.6)
Senegal (81)	25.9	76.2	France (47.6)
Serbia (757)	3.4	57.7	US (19.2), Croatia (19.2), Bosnia and Herzegovina (11.5)
Seychelles (4)	75.0	100.0	UK (33.3), South Africa (33.3), India (33.3)
Sierra Leone (31)	32.3	70.0	US (30.0), China (20.0), Italy (10.0), Australia (10.0), Russian Federation (10.0), Ethiopia (10.0)
Singapore (1308)	61.6	65.8	China (24.7), US (17.4), India (13.2), UK (10.5)
Sint Maarten (Dutch part) (1)	100.0	100.0	UK (100.0)
Slovakia (316)	10.1	62.5	Czech Republic (37.5)
Slovenia (329)	11.2	45.9	US (18.9), Italy (10.8)
Somalia (71)	39.4	67.9	Uganda (28.6), Kenya (14.3), Ethiopia (14.3), Sudan (10.7)
South Africa (2563)	20.1	46.2	UK (14.0), US (13.0)
South Sudan (11)	54.5	100.0	Kenya (33.3), Uganda (33.3), Bangladesh (16.7), Sudan (16.7)
Spain (19760)	9.2	38.2	Italy (11.2), US (10.3), UK (10.1)
Sri Lanka (593)	11.3	67.2	UK (28.4), India (17.9), US (13.4)

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Country of residence (# of observations)	% of immigrants	Concentration rate	Popular origins
Sudan (202)	14.9	60.0	UK (26.7), Egypt (13.3), South Africa (10.0), South Sudan (10.0)
Suriname (7)	71.4	100.0	Netherlands (40.0), China (20.0), Cuba (20.0), Belgium (20.0)
Svalbard and Jan Mayen (1)	100.0	100.0	US (100.0)
Swaziland (16)	75.0	58.3	South Africa (25.0), UK (16.7)
Sweden (7433)	24.9	31.5	
Switzerland (2921)	53.9	51.9	Germany (17.7), Italy (11.9), France (11.3), US (11.1)
Syrian Arab Republic (82)	26.8	86.4	France (68.2)
Taiwan, Province of China (3305)	26.1	87.4	US (70.6)
Tajikistan (19)	5.3	100.0	Russian Federation (100.0)
Tanzania, United Republic of (460)	13.9	42.2	UK (15.6), India (10.9)
Thailand (1046)	24.9	66.9	US (36.5), UK (16.2)
Timor-Leste (7)	85.7	100.0	Portugal (50.0), Indonesia (16.7), UK (16.7), Japan (16.7)
Togo (21)	23.8	80.0	Ghana (20.0), China (20.0), UK (20.0), France (20.0), Burkina Faso (20.0)
Trinidad and Tobago (51)	27.5	71.4	Jamaica (28.6), US (21.4), UK (14.3)
Tunisia (491)	12.8	90.5	France (71.4)
Turkey (5192)	7.5	73.5	US (45.0), UK (19.0)
Uganda (385)	14.0	51.9	UK (16.7), US (13.0), South Africa (13.0)
Ukraine (7051)	2.7	84.8	Russian Federation (73.3)
United Arab Emirates (553)	75.4	47.2	US (19.7), UK (10.8), India (10.3)
United Kingdom (23841)	27.4	32.5	US (12.4)
United States (64006)	21.9	46.2	China (20.3), India (11.3)
United States Minor Outlying Islands (1)	100.0	100.0	France (100.0)
Uruguay (211)	13.3	57.1	US (17.9), Spain (14.3), Argentina (14.3), France (10.7), Germany (10.7), Italy (10.7)
Uzbekistan (71)	15.5	100.0	Russian Federation (72.7)
Vanuatu (2)	50.0	100.0	India (100.0)
Venezuela, Bolivarian Republic of (668)	4.0	63.0	US (29.6), UK (11.1), Spain (11.1), France (11.1)
Viet Nam (698)	15.3	45.8	Russian Federation (14.0), France (12.1), US (11.2)
Virgin Islands, British (1)	100.0	100.0	Ukraine (100.0)
Virgin Islands, U.S. (6)	83.3	100.0	US (40.0), Australia (20.0), France (20.0), Puerto Rico (20.0)
Wallis and Futuna (1)	0.0	0.0	
Yemen (80)	42.5	64.7	Iraq (23.5), Malaysia (14.7), Egypt (14.7), India (11.8)
Zambia (148)	20.9	45.2	UK (19.4)
Zimbabwe (253)	14.2	55.6	South Africa (33.3), UK (11.1)
Åland Islands (1)	0.0	0.0	

Notes: this table calculates statistics comparable to columns 1–4 of Table 1 in (Franzoni et al. 2012); the origin of a scientist is defined to be the country of the scientist's first place of education or employment (whichever is earliest); scientists employed in a country different from their origin are defined as immigrants (in the destination country); popular origins are countries supplying 10+% of foreign workforce (exact share in parentheses); concentration rate is defined as the cumulative share of top four origins.

Table 5: Mobility patterns for all origins in 2015.

Country of origin (# of observations)	Emigrants (%)	% with international experience	Return migration (%)	Popular destinations
Afghanistan (20)	30.0	60.0	50.0	US (33.3), Australia (16.7), Pakistan (16.7), Netherlands (16.7), UK (16.7)
Albania (93)	17.2	41.9	59.0	Italy (25.0), Macedonia, the Former Yugoslav Republic of (25.0), US (12.5), UK (12.5)
Algeria (634)	10.6	20.8	49.2	Saudi Arabia (13.4), France (11.9), Qatar (10.4)
American Samoa (2)	50.0	100.0	50.0	Taiwan, Province of China (100.0)
Andorra (11)	9.1	45.5	80.0	Spain (100.0)
Angola (33)	18.2	66.7	72.7	Portugal (83.3), Spain (16.7)
Antigua and Barbuda (2)	50.0	100.0	50.0	US (100.0)
Argentina (1956)	20.2	33.0	38.7	US (28.5), Spain (19.9)
Armenia (116)	45.7	56.0	18.5	Russian Federation (30.2), US (15.1)
Aruba (2)	50.0	100.0	50.0	Belgium (100.0)
Australia (9580)	14.7	27.5	46.6	UK (20.2), US (19.4)
Austria (1826)	25.6	43.5	41.1	Germany (20.5), US (15.6), UK (10.7)

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Country of origin (# of observations)	Emigrants (%)	% with international experience	Return migration (%)	Popular destinations
Azerbaijan (86)	26.7	34.9	23.3	Turkey (30.4), Russian Federation (17.4)
Bahamas (7)	28.6	71.4	60.0	Australia (50.0), Azerbaijan (50.0)
Bahrain (38)	36.8	50.0	26.3	Qatar (50.0), Kuwait (14.3)
Bangladesh (1499)	26.0	54.0	52.0	US (18.3), Malaysia (14.4), Australia (14.4)
Barbados (13)	23.1	53.8	57.1	UK (66.7), Saint Kitts and Nevis (33.3)
Belarus (226)	44.2	50.4	12.3	Russian Federation (14.0), UK (12.0), Portugal (12.0), US (10.0)
Belgium (2191)	31.1	44.4	29.8	US (13.6), UK (11.7), France (10.4)
Belize (2)	0.0	50.0	100.0	
Benin (40)	22.5	50.0	55.0	Senegal (22.2), France (11.1), Burkina Faso (11.1), US (11.1), China (11.1), Cameroon (11.1)
Bermuda (2)	0.0	0.0	·	
Bhutan (27)	7.4	48.1	84.6	Nepal (50.0), Netherlands (50.0)
Bolivia, Plurinational State of (80)	23.8	57.5	58.7	Brazil (21.1), Spain (21.1), Peru (10.5), Chile (10.5), Sweden (10.5)
Bosnia and Herzegovina (141)	19.9	36.2	45.1	Turkey (10.7), Serbia (10.7), UK (10.7)
Botswana (61)	18.0	49.2	63.3	South Africa (27.3), Australia (18.2), Zimbabwe (18.2)
Bouvet Island (1)	0.0	0.0	·	
Brazil (19480)	4.9	15.7	68.5	US (29.8), Portugal (13.9)
British Indian Ocean Territory (1)	0.0	0.0	·	
Brunei Darussalam (24)	4.2	33.3	87.5	UK (100.0)
Bulgaria (506)	27.7	36.8	24.7	US (16.4), UK (14.3)
Burkina Faso (48)	16.7	41.7	60.0	France (25.0), Niger (12.5), Togo (12.5), Sweden (12.5), Chad (12.5), US (12.5)
Burundi (3)	66.7	100.0	33.3	Sweden (50.0), Tanzania, United Republic of (50.0)
Cambodia (27)	22.2	55.6	60.0	Japan (16.7), Spain (16.7), US (16.7), Ecuador (16.7), New Zealand (16.7), France (16.7)
Cameroon (198)	20.2	37.9	46.7	South Africa (20.0), US (12.5), UK (10.0)
Canada (6598)	35.4	47.6	25.7	US (43.1), UK (10.6)
Cape Verde (13)	23.1	61.5	62.5	Portugal (66.7), Brazil (33.3)
Cayman Islands (1)	100.0	100.0	0.0	US (100.0)
Central African Republic (3)	0.0	66.7	100.0	
Chad (3)	0.0	0.0	·	
Chile (1472)	13.4	45.0	70.3	US (23.9), Spain (15.2)
China (17921)	28.5	44.0	35.2	US (55.7)
Cocos (Keeling) Islands (1)	100.0	100.0	0.0	Colombia (100.0)
Colombia (5454)	8.8	35.9	75.5	US (25.0), Spain (19.6)
Congo (5)	60.0	60.0	0.0	South Africa (33.3), France (33.3), Sweden (33.3)
Congo, the Democratic Republic of the (69)	29.0	59.4	51.2	South Africa (25.0), Belgium (10.0), Canada (10.0), Zambia (10.0), Benin (10.0)
Cook Islands (1)	0.0	0.0	·	
Costa Rica (294)	12.6	45.2	72.2	US (35.1), Spain (13.5)
Croatia (586)	16.6	26.5	37.4	US (18.6), UK (16.5)
Cuba (680)	41.2	53.1	22.4	Spain (22.1), Ecuador (20.7)
Cyprus (129)	24.8	52.7	52.9	UK (40.6), Turkey (12.5)
Czech Republic (1335)	14.6	26.6	45.1	US (13.8)
Côte d'Ivoire (53)	15.1	30.2	50.0	France (37.5), Turkey (12.5), Burkina Faso (12.5), Canada (12.5), Brazil (12.5), Kenya (12.5)
Denmark (3696)	10.7	22.7	52.8	US (21.2), Sweden (16.2), UK (12.4)
Djibouti (5)	20.0	80.0	75.0	China (100.0)
Dominica (4)	75.0	75.0	0.0	US (66.7), Saudi Arabia (33.3)
Dominican Republic (77)	20.8	62.3	66.7	US (68.8), Spain (18.8)
Ecuador (830)	8.4	41.2	79.5	Spain (28.6), US (22.9)
Egypt (4359)	18.8	36.9	49.0	Saudi Arabia (31.1), US (16.2)
El Salvador (53)	13.2	39.6	66.7	Spain (42.9), Mexico (14.3), Nicaragua (14.3), US (14.3), Poland (14.3)
Eritrea (12)	50.0	66.7	25.0	US (33.3), Netherlands (16.7), Australia (16.7), Ethiopia (16.7), South Africa (16.7)
Estonia (212)	17.9	35.8	50.0	UK (15.8), Sweden (13.2), Finland (13.2), US (13.2)
Ethiopia (765)	9.0	31.9	71.7	US (30.4), Sweden (10.1)
Faroe Islands (4)	25.0	50.0	50.0	Denmark (100.0)
Fiji (33)	39.4	63.6	38.1	Australia (46.2)
Finland (1697)	15.1	26.8	43.5	Sweden (24.1), US (14.8), UK (11.7)
France (8572)	31.5	44.2	28.8	US (15.4), UK (10.7)
French Guiana (5)	20.0	20.0	0.0	Belgium (100.0)
French Polynesia (8)	12.5	12.5	0.0	Finland (100.0)
French Southern Territories (2)	50.0	50.0	0.0	France (100.0)
Gabon (9)	11.1	44.4	75.0	US (100.0)
Gambia (17)	11.8	29.4	60.0	UK (100.0)

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Country of origin (# of observations)	Emigrants (%)	% with international experience	Return migration (%)	Popular destinations
Georgia (118)	22.9	38.1	40.0	Germany (18.5), Russian Federation (18.5), UK (11.1)
Germany (8919)	34.7	48.7	28.6	US (18.4), UK (12.9)
Ghana (672)	14.0	42.3	66.9	US (26.6), UK (18.1)
Gibraltar (1)	0.0	0.0	·	
Greece (1980)	41.2	61.2	32.7	UK (28.7), US (16.6)
Grenada (9)	55.6	66.7	16.7	US (100.0)
Guadeloupe (10)	40.0	50.0	20.0	France (75.0), Trinidad and Tobago (25.0)
Guam (6)	16.7	83.3	80.0	US (100.0)
Guatemala (86)	31.4	57.0	44.9	US (40.7), Mexico (18.5), Spain (11.1)
Guinea (8)	12.5	25.0	50.0	Chad (100.0)
Guyana (3)	66.7	66.7	0.0	Trinidad and Tobago (50.0), Japan (50.0)
Haiti (10)	40.0	80.0	50.0	US (50.0), Canada (25.0), France (25.0)
Holy See (Vatican City State) (1)	100.0	100.0	0.0	Italy (100.0)
Honduras (41)	39.0	70.7	44.8	US (43.8), Spain (12.5), Ecuador (12.5)
Hong Kong (501)	33.3	48.9	31.8	China (26.3), US (25.7), UK (12.6)
Hungary (1497)	19.5	30.7	36.4	US (17.5), UK (14.7)
Iceland (127)	28.3	61.4	53.8	Sweden (30.6), Denmark (19.4), US (13.9)
India (20758)	19.9	26.8	25.6	US (38.3)
Indonesia (3007)	6.0	39.9	85.1	Malaysia (18.4), Japan (15.1), Australia (13.4)
Iran, Islamic Republic of (4766)	18.8	29.6	36.4	US (28.7), Canada (9.9)
Iraq (722)	19.5	47.5	58.9	Malaysia (17.0), UK (14.9), US (12.8)
Ireland (1417)	36.4	54.6	33.2	UK (45.7), US (14.9)
Isle of Man (5)	40.0	40.0	0.0	UK (100.0)
Israel (926)	30.5	48.6	37.3	US (56.7)
Italy (18274)	15.0	27.5	45.4	UK (18.9), US (15.3)
Jamaica (45)	40.0	64.4	37.9	US (38.9), Trinidad and Tobago (22.2), UK (16.7), Barbados (11.1)
Japan (5758)	19.5	31.0	37.2	US (24.9), Korea, Republic of (10.5)
Jersey (2)	0.0	100.0	100.0	
Jordan (574)	38.9	69.0	43.7	Saudi Arabia (26.0), US (17.5), Qatar (10.8), United Arab Emirates (10.3)
Kazakhstan (309)	11.3	21.7	47.8	Russian Federation (51.4)
Kenya (802)	10.5	34.2	69.3	US (19.0), UK (14.3)
Korea, Democratic People's Republic of (3)	66.7	66.7	0.0	Korea, Republic of (50.0), China (50.0)
Korea, Republic of (6819)	11.8	30.3	60.9	US (60.0)
Kuwait (81)	14.8	55.6	73.3	Jordan (25.0), Qatar (16.7)
Kyrgyzstan (46)	21.7	34.8	37.5	Russian Federation (30.0), US (20.0), Kazakhstan (20.0), Switzerland (10.0), Nepal (10.0), Colombia (10.0)
Lao People's Democratic Republic (7)	0.0	42.9	100.0	
Latvia (290)	14.5	22.4	35.4	Sweden (16.7), US (14.3), Russian Federation (14.3), UK (11.9)
Lebanon (305)	47.9	69.8	31.5	US (32.9), France (14.4), Qatar (13.7)
Lesotho (16)	68.8	81.2	15.4	South Africa (90.9)
Liberia (18)	22.2	38.9	42.9	US (50.0), China (50.0)
Libya (78)	25.6	71.8	64.3	US (25.0), UK (20.0), Malaysia (10.0)
Liechtenstein (5)	20.0	40.0	50.0	Czech Republic (100.0)
Lithuania (343)	17.2	25.7	33.0	US (13.6), Sweden (13.6)
Luxembourg (39)	23.1	41.0	43.8	Italy (22.2), Portugal (11.1), Germany (11.1), Ireland (11.1), Netherlands (11.1), South Africa (11.1)
Macao (13)	23.1	23.1	0.0	US (33.3), Portugal (33.3), Netherlands (33.3)
Macedonia, the Former Yugoslav Republic of (132)	18.2	31.8	42.9	Australia (12.5)
Madagascar (37)	13.5	40.5	66.7	France (40.0), Burkina Faso (20.0), Mauritius (20.0), Switzerland (20.0)
Malawi (119)	10.9	61.3	82.2	UK (38.5), South Africa (23.1), Lesotho (15.4), US (15.4)
Malaysia (2820)	10.0	34.6	71.2	Iran, Islamic Republic of (11.7), Australia (10.7), Saudi Arabia (10.0)
Maldives (5)	60.0	100.0	40.0	India (33.3), New Zealand (33.3), Thailand (33.3)
Mali (17)	5.9	64.7	90.9	US (100.0)
Malta (54)	33.3	70.4	52.6	UK (50.0), US (11.1), Italy (11.1)
Marshall Islands (1)	0.0	0.0	·	
Martinique (4)	50.0	50.0	0.0	UK (50.0), Canada (50.0)
Mauritius (20)	35.0	40.0	12.5	US (14.3), China (14.3), UK (14.3), Canada (14.3), South Africa (14.3), Côte d'Ivoire (14.3)
Mexico (4654)	9.5	26.6	64.4	US (30.9), Spain (12.7)
Moldova, Republic of (49)	59.2	71.4	17.1	Ukraine (31.0), Switzerland (10.3), Russian Federation (10.3)

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Country of origin (# of observations)	Emigrants (%)	% with international experience	Return migration (%)	Popular destinations
Monaco (3)	0.0	0.0	·	
Mongolia (51)	13.7	43.1	68.2	Korea, Republic of (28.6), Japan (14.3), Russian Federation (14.3), Australia (14.3), US (14.3), China (14.3)
Montenegro (18)	0.0	50.0	100.0	
Morocco (294)	15.0	28.9	48.2	US (15.9)
Mozambique (81)	11.1	65.4	83.0	Portugal (88.9), South Africa (11.1)
Myanmar (93)	29.0	46.2	37.2	Malaysia (22.2), US (22.2), Thailand (18.5), Australia (11.1)
Namibia (24)	29.2	66.7	56.2	South Africa (28.6), China (14.3), Sweden (14.3), Tanzania, United Republic of (14.3), Botswana (14.3), US (14.3)
Nepal (382)	23.0	42.7	46.0	US (33.0)
Netherlands (4019)	30.4	42.5	28.6	UK (18.8), US (14.7)
New Caledonia (7)	14.3	28.6	50.0	Switzerland (100.0)
New Zealand (1456)	33.9	48.8	30.7	Australia (40.2), UK (18.7), US (14.2)
Nicaragua (60)	20.0	51.7	61.3	US (25.0), Spain (16.7)
Niger (10)	30.0	60.0	50.0	Chad (33.3), France (33.3), South Africa (33.3)
Nigeria (2748)	12.1	31.2	61.1	US (20.4), UK (16.8), South Africa (14.7)
Norway (1289)	11.6	22.4	48.4	Sweden (21.5)
Oman (77)	3.9	54.5	92.9	Egypt (33.3), United Arab Emirates (33.3), Australia (33.3)
Pakistan (2675)	19.7	41.3	52.4	Saudi Arabia (17.9), US (16.9)
Palau (1)	0.0	100.0	100.0	
Palestine, State of (113)	28.3	62.8	54.9	
Panama (54)	25.9	66.7	61.1	US (28.6), Colombia (14.3)
Papua New Guinea (21)	14.3	66.7	78.6	Australia (33.3), Ireland (33.3), New Zealand (33.3)
Paraguay (155)	8.4	42.6	80.3	Spain (30.8), Brazil (23.1), Italy (23.1)
Peru (931)	15.8	34.9	54.8	US (25.9), Brazil (21.1), Spain (17.7)
Philippines (1883)	8.7	15.9	45.3	US (28.7)
Poland (2338)	20.9	32.1	34.8	UK (19.8), US (19.0)
Portugal (12054)	8.5	27.2	68.8	UK (19.5), US (12.4)
Puerto Rico (174)	39.1	64.9	39.8	US (80.9)
Qatar (273)	3.3	29.3	88.8	US (55.6), Kuwait (11.1), Egypt (11.1), Belgium (11.1), Italy (11.1)
Romania (1755)	21.0	32.6	35.7	US (15.5), UK (15.2)
Russian Federation (12028)	12.1	15.5	22.1	US (20.1)
Rwanda (80)	12.5	75.0	83.3	US (20.0), Canada (20.0), Netherlands (20.0), Belgium (10.0), South Africa (10.0), Spain (10.0)
Réunion (24)	29.2	41.7	30.0	Switzerland (28.6), France (14.3), Portugal (14.3), Mauritius (14.3), Korea, Republic of (14.3), US (14.3)
Saint Barthélemy (1)	100.0	100.0	0.0	Russian Federation (100.0)
Saint Kitts and Nevis (3)	66.7	66.7	0.0	US (100.0)
Saint Martin (French part) (1)	100.0	100.0	0.0	US (100.0)
Samoa (1)	0.0	100.0	100.0	
San Marino (1)	100.0	100.0	0.0	Italy (100.0)
Sao Tome and Principe (1)	100.0	100.0	0.0	Portugal (100.0)
Saudi Arabia (1050)	7.4	41.0	81.9	US (33.3), Egypt (12.8)
Senegal (78)	23.1	47.4	51.4	US (22.2), Mali (11.1), Rwanda (11.1)
Serbia (894)	18.2	25.4	28.2	US (17.8), UK (14.7)
Seychelles (3)	66.7	100.0	33.3	US (50.0), Switzerland (50.0)
Sierra Leone (29)	27.6	44.8	38.5	US (25.0), Somalia (12.5), Malaysia (12.5), Australia (12.5), China (12.5), UK (12.5)
Singapore (736)	31.8	48.6	34.6	US (19.2), Australia (15.8), China (12.8), UK (10.7)
Sint Maarten (Dutch part) (3)	100.0	100.0	0.0	US (100.0)
Slovakia (382)	25.7	38.2	32.9	Czech Republic (31.6), UK (10.2)
Slovenia (356)	18.0	29.8	39.6	UK (23.4), Austria (14.1)
Somalia (46)	6.5	28.3	76.9	UK (66.7), Kenya (33.3)
South Africa (2452)	16.5	27.1	39.2	US (17.1), UK (17.1), Australia (15.3)
South Sudan (9)	44.4	66.7	33.3	Sudan (75.0), Somalia (25.0)
Spain (20485)	12.4	23.7	47.4	UK (15.7), US (14.7)
Sri Lanka (672)	21.7	43.5	50.0	Australia (27.4), US (23.3), UK (19.9)
Sudan (313)	45.0	64.5	30.2	Saudi Arabia (41.8), Qatar (14.2)
Suriname (3)	33.3	33.3	0.0	Netherlands (100.0)
Svalbard and Jan Mayen (1)	100.0	100.0	0.0	Poland (100.0)
Swaziland (11)	63.6	90.9	30.0	South Africa (42.9), Canada (14.3), Sweden (14.3), Switzerland (14.3), Germany (14.3)
Sweden (6294)	11.3	22.2	49.2	US (17.4), Denmark (12.5), UK (10.4)
Switzerland (2035)	33.8	50.2	32.8	US (20.2), UK (12.8), Germany (10.3)

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Country of origin (# of observations)	Emigrants (%)	% with international experience	Return migration (%)	Popular destinations
Syrian Arab Republic (182)	67.0	76.9	12.9	US (18.9), UK (15.6), Saudi Arabia (12.3)
Taiwan, Province of China (2847)	14.3	32.7	56.4	US (54.9)
Tajikistan (22)	18.2	27.3	33.3	Russian Federation (50.0), Iran, Islamic Republic of (25.0), US (25.0)
Tanzania, United Republic of (420)	5.7	36.7	84.4	Uganda (20.8), UK (12.5)
Thailand (898)	12.5	47.0	73.5	US (21.4)
Timor-Leste (1)	0.0	100.0	100.0	
Togo (26)	38.5	61.5	37.5	US (20.0), France (20.0), Burkina Faso (10.0), Colombia (10.0), India (10.0), Brazil (10.0)
Tonga (2)	100.0	100.0	0.0	New Zealand (50.0), US (50.0)
Trinidad and Tobago (52)	28.8	50.0	42.3	US (46.7), UK (40.0)
Tunisia (526)	18.6	33.1	43.7	Saudi Arabia (29.6), Qatar (20.4), France (14.3)
Turkey (5331)	9.9	23.6	58.0	US (40.5), UK (12.7)
Turkmenistan (5)	100.0	100.0	0.0	Russian Federation (60.0), Turkey (20.0), Ukraine (20.0)
Uganda (407)	18.7	44.7	58.2	South Africa (11.8), Kenya (10.5), US (10.5), Somalia (10.5)
Ukraine (7369)	6.9	10.0	30.7	Russian Federation (28.7), US (12.2)
United Arab Emirates (163)	16.6	42.9	61.4	US (18.5), Canada (14.8), Saudi Arabia (11.1)
United Kingdom (23556)	26.5	35.6	25.5	US (16.8), Australia (12.0)
United States (58179)	14.1	19.0	25.9	
United States Minor Outlying Islands (1)	100.0	100.0	0.0	US (100.0)
Uruguay (224)	18.3	47.8	61.7	Spain (19.5), US (14.6), Mexico (14.6)
Uzbekistan (102)	41.2	48.0	14.3	Russian Federation (38.1)
Vanuatu (2)	50.0	100.0	50.0	France (100.0)
Venezuela, Bolivarian Republic of (892)	28.1	48.8	42.3	Spain (22.3), US (19.9), Colombia (14.3)
Viet Nam (744)	20.6	65.5	68.6	Australia (19.6), US (19.0)
Virgin Islands, U.S. (1)	0.0	100.0	100.0	
Wallis and Futuna (1)	0.0	0.0	·	
Yemen (66)	30.3	68.2	55.6	Saudi Arabia (55.0), Malaysia (30.0), Qatar (10.0)
Zambia (129)	9.3	52.7	82.4	South Africa (41.7), UK (16.7)
Zimbabwe (312)	30.4	53.2	42.8	South Africa (49.5), UK (14.7)
Åland Islands (2)	50.0	50.0	0.0	Bonaire, Sint Eustatius and Saba (100.0)

Notes: this table calculates statistics comparable to columns 5–9 of Table 1 in (Franzoni et al. 2012); the origin of a scientist is defined to be the country of the scientist's first place of education or employment (whichever is earliest); popular destinations are countries where 10+% of origin scientists were in 2010 (exact share in parentheses); migration experience is defined as observation of studying or working for at least one year in a country different from the imputed country of origin; rate of return migration is calculated as the ratio of origin scientists that have international experience and were employed in the origin country in 2010 to the total number of origin scientists with international experience employed in 2010 (in any country).