5-1-2012

# FOREIGN BORN SCIENTISTS: MOBILITY PATTERNS FOR SIXTEEN COUNTRIES

Chiara Franzoni
*Politecnico di Milano*, chiara.franzoni@polimi.it

Giuseppe Scellato
*Politecnico di Torino*, giuseppe.scellato@polito.it

Paula Stephan
*Georgia State University*, pstephan@gsu.edu

W.J. Usery Workplace Research Group Paper Series

Working Paper 2012-5-1
May 2012

# Foreign Born Scientists: Mobility Patterns for Sixteen Countries

Chiara Franzoni
Politecnico di Milano

Giuseppe Scellato
Politecnico di Torino

Paula Stephan
Georgia State University

*This paper can be downloaded at: http://aysps.gsu.edu/uwrg-research.html*

Georgia State University | Andrew Young School of Policy Studies

NBER WORKING PAPER SERIES

# FOREIGN BORN SCIENTISTS: MOBILITY PATTERNS FOR SIXTEEN COUNTRIES

Chiara Franzoni
Giuseppe Scellato
Paula Stephan

Working Paper 18067
http://www.nber.org/papers/w18067

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 2012

The authors acknowledge support from Regione Piemonte for the GlobSci project and from the IPE Program, National Bureau of Economic Research. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

Foreign Born Scientists: Mobility Patterns for Sixteen Countries
Chiara Franzoni, Giuseppe Scellato, and Paula Stephan
NBER Working Paper No. 18067
May 2012
JEL No. F32,J24,O30


## ABSTRACT

We report results from the first systematic study of the mobility of scientists engaged in research in a large number of countries. Data were collected from 17,182 respondents using a web-based survey of corresponding authors in 16 countries in four fields during 2011. We find considerable variation across countries, both in terms of immigration and emigration patterns. Switzerland has the largest percent of immigrant scientists working in country (56.7); Canada, and Australia trail by nine or more percent; the U.S. and Sweden by approximately eighteen percent. India has the lowest (0.8), followed closely by Italy and Japan. The most likely reason to come to a country for postdoctoral study or work is professional. Our survey methodology also allows us to study emigration patterns of individuals who were living in one of the 16 countries at age 18. Again, considerable variation exists by country. India heads the list with three in eight of those living in country when they were 18 out of country in 2011. The country with the lowest diaspora is Japan. Return rates also vary by country, with emigrants from Spain being most likely to return and those from India being least like to return. Regardless of country, the most likely reason respondents report for returning to one's home country is family or personal.



Chiara Franzoni
Politecnico di Milano
Dipartimento di Ingegneria Gestionale (DIG)
Piazza Leonardo da Vinci, 32
Milano ITALY 20133
chiara.franzoni@polimi.it

Giuseppe Scellato
Department of Production Systems
and Business Economics
Politecnico di Torino
10129 Turin, Italy
giuseppe.scellato@polito.it

Paula Stephan
Department of Economics
Andrew Young School of Policy Studies
Georgia State University
Box 3992
Atlanta, GA 30302-3992
and NBER
pstephan@gsu.edu

## 1. Introduction

Scientists are known to be a highly mobile group.[1] A recent study of postdoctoral researchers working in Europe in the life sciences, for example, found that 43 percent were working in a country different than that of origin (Empirica 2005). In the United States, 41.6 percent of those with doctorates working in a science and engineering occupation in 2009 were born outside the United States (National Science Board, 2012, table 3-28). Currently, approximately 48 percent of all PhDs awarded in the United States go to those who are either temporary or permanent residents. Almost 60 percent of all postdocs working in the United States are on a temporary visa. (Stephan 2012). Moreover, highly productive scientists are even more mobile than the underlying scientific population. Hunter et al. (2009), for example, found that 50 percent of all the highly-cited PhD physicists in the world work in a different country than that in which they were born. Levin and Stephan (1999) found exceptionally productive scientists and engineers working in the United States, defined by a number of measures, to have a higher probability of being foreign born and foreign educated than the underlying population of U.S. scientists.

Despite the importance of the foreign born, it is difficult to make cross-country comparisons regarding the role of the foreign born and their country of origin because of problems that arise in collecting consistent data across countries.[2] Moreover, most countries have an incomplete picture of the migration patterns of scientists born in their country because of difficulty in tracking individuals working outside their country of origin.[3]

## 2. The GlobSci Survey

To provide consistent cross-country data on active researchers, we surveyed corresponding authors of articles published in 2009 in four fields of science who were studying or working in one of 16 "core" countries.[4] The four fields are biology, chemistry, earth and environmental sciences, and materials. They were chosen in part because 95 percent or more of

[1] See, for example, Auriol (2010); Auriol (2007) and Emperica (2005).
[2] Two recent studies have gathered data on mobility of doctorate holders: Careers of Doctorate Holders (CDH) developed by OECD and UNESCO (Auriol, 2010) and the MORE study (2011), funded by the European Commission. The CDH study focuses on all doctorate holders; data reported vary by date, depending upon country.
[3] By way of example, the National Science Foundation's Survey of Doctorate Recipients does not track individuals. trained in the United States who subsequently leave the United States
[4] The sixteen core countries are Australia, Belgium, Brazil, Canada, Denmark, France, Germany, India, Italy, Japan, Netherlands, Spain, Sweden, Switzerland, UK, U.S.

all articles published in these disciplines contain the corresponding author's email address.[5] The survey was administered during the period February to June of 2011. Collectively these core countries produce about 70 percent of all articles published in these fields.[6] The only high-producing country not represented in the GlobSci survey is China, where efforts to field the web-based survey proved unsuccessful. For each specific discipline, we chose articles from a randomly picked selection of journals in each quartile of the Impact Factor distribution. (See Appendix for a discussion of the sampling methodology, survey administration and response rate bias; go to http://www.dig.polimi.it/uploads/media/GlobSci_survey.pdf to see a copy of the questionnaire).

**Table 1 - Response rates by country**

| Core country | Panels | Total Answers | Of which complete | Of which dropout | Total Response Rate % | Complete Response Rate % |
|---|---|---|---|---|---|---|
| Belgium | 706 | 302 | 244 | 58 | 42.8 | 34.6 |
| Brazil | 1,537 | 762 | 692 | 70 | 49.6 | 45.0 |
| Canada | 2,455 | 1,020 | 897 | 123 | 41.5 | 36.5 |
| Denmark | 513 | 227 | 208 | 19 | 44.2 | 40.5 |
| France | 3,839 | 1,618 | 1,367 | 251 | 42.1 | 35.6 |
| Germany | 4,380 | 1,326 | 1,147 | 179 | 30.3 | 26.2 |
| India | 1,380 | 627 | 484 | 143 | 45.4 | 35.1 |
| Italy | 2,779 | 1,917 | 1,759 | 158 | 69.0 | 63.3 |
| Japan | 5,250 | 1,860 | 1,678 | 182 | 35.4 | 32.0 |
| Netherlands | 1,036 | 391 | 345 | 46 | 37.7 | 33.3 |
| Spain | 2,303 | 1,228 | 1,080 | 148 | 53.3 | 46.9 |
| Sweden | 882 | 353 | 301 | 52 | 40.0 | 34.1 |
| Switzerland | 919 | 356 | 320 | 36 | 38.7 | 34.8 |
| UK | 3,695 | 1,355 | 1,183 | 172 | 36.7 | 32.0 |
| U.S. | 14,059 | 5,165 | 4,512 | 653 | 36.7 | 32.1 |
| Total | 47,304 | 19,183 | 16,827 | 2,356 | 40.6 | 35.6 |

Response rates by country are given in Table 1. The overall response rate of 35.6 percent (unadjusted for non-deliverables) is 10 to 25 points higher than that for most web-based surveys

[5] In 2009 the estimated number of records that did not report email address for corresponding author was 0.9% in biology, 3.6% in chemistry, 2.9% in earth and environmental sciences and 4.5% in materials science.
[6] SCImago.

(Sauermann and Roach 2011b).[7] The median country response rate was approximately the same. This resulted in 16,827 completed responses; an additional 2,356 respondents answered part but not all of the questions posed (40.6 percent of the sample). Response rates vary somewhat by country, being highest for Italy (63.3 percent) and lowest for Germany (26.2 percent). Ten countries had overall response rates between 32.0 and 36.5 percent. Differences likely reflect in part the degree to which similar populations of scientists have been surveyed in the recent past by other, unrelated studies.[8] (See Appendix for more details concerning response rate.)

### 3. Immigration Patterns: Country of work or study 2011

Country of origin was determined by asking the respondent to report country of residence at age 18. Data for the 17,182 (36.3 percent of the sample) scientists for whom country of origin and country of residence in 2011 could be determined are summarized in the left hand panel (columns 1-3) of the Table 2 and show considerable variation in the percent foreign working or studying in country. Switzerland heads the list. More than one out of two scientists studying or working in Switzerland in 2011 lived abroad at age 18. Canada is a distant second, being 9.8 percentage points lower, followed closely by Australia (44.5 percent), and then by the United States with 38.4 percent and Sweden with 37.6. A number of countries have an extremely low percent of foreign scientists studying or working in the country. Particularly notable is the virtual absence of foreign scientists studying or working in India, followed closely by Italy with 3.0 percent, Japan with 5.0 percent, Brazil with 7.1 percent and Spain with 7.3 percent.

For many countries, "neighbors" are the most likely source of immigrants (column 3). For example, Germany is the most likely country of origin of immigrant scientists in the Netherlands as well as immigrant scientists studying or working in Belgium, Denmark, Sweden and Switzerland. Argentina, Columbia and Peru are important source countries for those working or studying in Brazil. The United States is a major source country for foreigners working or studying in Canada. For foreign scientists working or studying in Japan the most likely countries of origin are China and South Korea. But cultural/language ties also matter: the UK is the top source country for Australia and is tied for top place as the source country for

[7] Walsh, Cohen and Cho (2007) find in a sample of U.S. scientists that undelivered emails accounted for approximately 3.2 percent. Sauermann and Roach (2011b) find that undelivered emails accounted for 6.3 percent in a sample of junior U.S. scientists.
[8] Haeussler (2001) and Sauermann and Roach (2011a) provide two recent examples.

foreigners in Canada; Argentina is the major source country for Spain. But geography and language do not always dominate. The top source country for the U.S. is China. The top source country for the UK is Germany, followed by Italy.

**Table 2 - Mobility Patterns for Sixteen Countries**

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|
| Country of work or study in 2011 | Share outside country at 18 | Countries supplying 10% or more of foreign workforce | Country of origin at 18 | Share currently outside country | Destination countries with more than 10% of natives abroad | Share with inter-national experience | Rate of return of those with intern-national experience |
| Obs. 17,182 (number) | % | (%) | Obs. 15,115 (number) | % | (%) | % | % |
| Australia (629) | 44.5 | UK (21.1)<br>China (12.5) | Australia (418) | 18.3 | U.S. (45.8)<br>UK (24.7) | 62.9 | 70.8 |
| Belgium (253) | 18.2 | Germany (15.2)<br>France (15.2)<br>Italy (13.0) | Belgium (261) | 21.7 | France (30.0)<br>U.S. (20.0)<br>UK (10.2) | 52.8 | 58.9 |
| Brazil (702) | 7.1 | Argentina (16.0)<br>France (14.0)<br>Columbia (12.0)<br>Peru (12.0) | Brazil (700) | 8.3 | U.S. (34.0)<br>Canada (15.7)<br>Germany (15.5) | 51.1 | 83.7 |
| Canada (902) | 46.9 | UK (13.5)<br>U.S (13.5)<br>China (10.9) | Canada (613) | 23.7 | U.S. (70.1) | 66.8 | 64.4 |
| Denmark (206) | 21.8 | Germany (24.4) | Denmark (183) | 13.3 | UK. (37.5)<br>U.S. (36.4) | 54.3 | 75.4 |
| France (1380) | 17.3 | Italy (13.8) | France (1303) | 13.2 | U.S. (22.8)<br>UK (14.5)<br>Canada (14.0) | 59.2 | 77.7 |
| Germany (1187) | 23.2 | None | Germany (1254) | 23.3 | U.S. (29.5)<br>Switzerland (19.1)<br>UK (18.0) | 58.0 | 59.9 |
| India (525) | 0.8 | * | India (806) | 39.8 | U.S. (75.1) | 75.1 | 47.1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Italy (1792) | 3.0 | France (13.0)<br>Germany (11.1)<br>Spain (11.1) | Italy (1938) | 16.2 | U.S. (25.0)<br>UK (19.7)<br>France (15.5)<br>Germany (10.7) | 40.0 | 59.5 |
| Japan (1707) | 5.0 | China (33.7)<br>S. Korea (11.6) | Japan (1676) | 3.1 | U.S. (51.4) | 39.5 | 92.0 |
| Netherlands (347) | 27.7 | Germany (14.6)<br>Italy (12.5) | Netherlands (339) | 26.4 | U.S. (22.9)<br>UK (19.5)<br>Germany (18.8) | 53.1 | 50.3 |
| Spain (1185) | 7.3 | Argentina (12.6)<br>France (10.3)<br>Italy (10.3) | Spain (1175) | 8.4 | U.S. (31.0)<br>Germany (16.2)<br>UK (15.5)<br>France (14.1) | 63.1 | 86.7 |
| Sweden (314) | 37.6 | Germany (11.9)<br>Russian F. (10.2) | Sweden (226) | 13.9 | U.S. (23.8)<br>UK (13.8)<br>Germany (11.5) | 53.9 | 74.2 |
| Switzerland (330) | 56.7 | Germany (36.9) | Switzerland (209) | 33.1 | U.S. (34.2)<br>Germany (29.5) | 78.4 | 57.8 |
| UK (1205) | 32.9 | Germany (15.2)<br>Italy (10.4) | UK (1090) | 25.1 | U.S. (46.9)<br>Canada (16.6)<br>Australia (16.6) | 56.4 | 55.4 |
| U.S. (4518) | 38.4 | China (16.9)<br>India (12.3) | U.S. (2924) | 5.0 | Canada (32.2)<br>UK (16.3)<br>Australia (10.1)<br>Germany (10.0) | 19.2 | 74.2 |

*Number of foreigners is too small to provide meaningful statistics

Countries also vary in the degree of diversity of immigrants who work in country, measured by the percent of immigrant researchers from the top-four source countries (four-country concentration rate, given in Table 3). High concentration rates indicate less diversity. Countries with the highest concentration rates are Japan and Switzerland (approximately six out of ten immigrant scientists working or studying there hail from one of four countries). Brazil and Belgium are not far behind, with concentration rates in the 50's. Countries with lower concentration rates, reflecting more diversity, include Denmark, Australia, Canada, the United States, Italy, the Netherlands, and Spain. The countries with the highest amount of diversity are Germany and Sweden, where only about one out of three immigrants come from one of four countries.

The four-country concentration rate measures the percent of a country's foreign scientific population coming from the top four source countries. In order to provide a global measure of diversity of foreign born researchers and PhD students in each of the core countries, we compute the Herfindahl–Hirschman concentration index (H) of the shares of immigrants by current country, reported in column 2 of Table 3 (Hirschman, 1964). The H index is a standard indicator used to measure market concentration. For each core country i, the corresponding H index is computed as follows:

$$H_i = \sum_{j=1}^{C} \left( s_j^2 \right) * 100$$

$$s_j = \frac{N_j}{N_{tot}}$$

where C is the total number of source countries and $s_j$ is the share of immigrants in country i from country j with respect to the total number of immigrants in country i. Higher values of the H index indicate higher geographic concentration of the immigrants, with an upper bound value of 100. The lower bound of the indicator is given by H=(1/C)*100. This would be the case for a core country that has the same number of immigrants from all possible source countries (127 countries in our dataset, with a corresponding lower bound of 0.79). By construction the indicator tends to give more weight to larger shares.

**Table 3– Indicators of geographical concentration of foreign born scientists currently working or studying in one of the core countries**

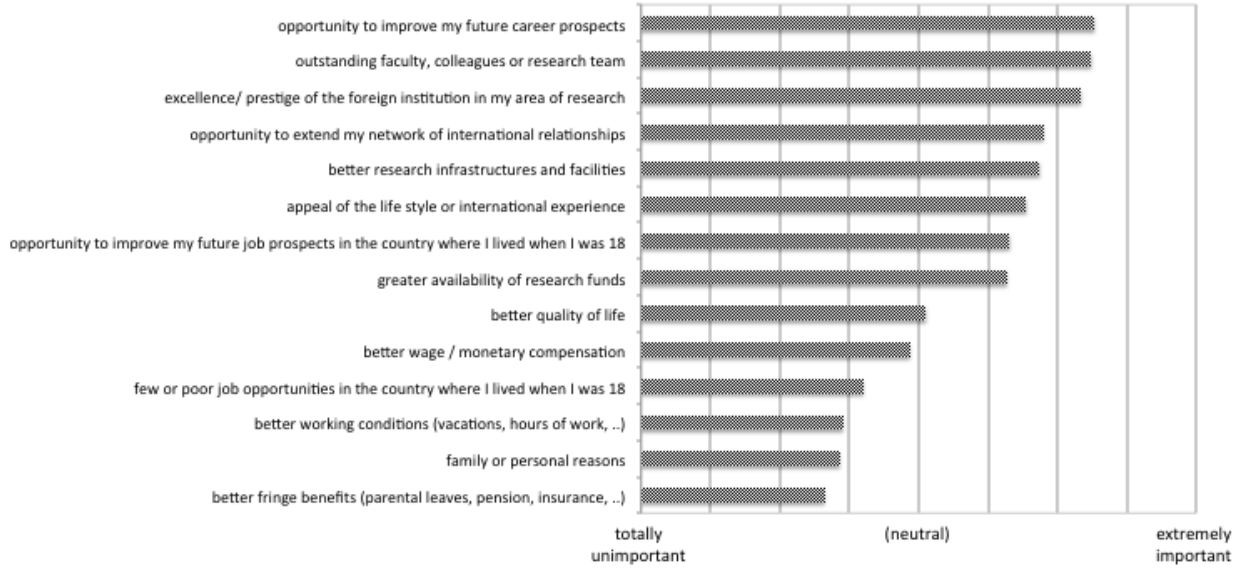
| Current country of Work or study | Four country concentration rate | H index of concentration |
|---|---|---|
| Australia | 43.6 | 7.7 |
| Belgium | 52.2 | 8.7 |
| Brazil | 54.0 | 8.7 |
| Canada | 43.3 | 6.3 |
| Denmark | 44.5 | 9.4 |
| France | 37.2 | 5.9 |
| Germany | 30.2 | 4.2 |
| India | 100 | * |
| Italy | 42.6 | 6.8 |
| Japan | 60.5 | 14.8 |

| | | |
|---|---|---|
| Netherlands | 40.6 | 6.2 |
| Spain | 40.2 | 6.2 |
| Sweden | 34.7 | 5 |
| Switzerland | 59.4 | 16.3 |
| UK | 37.6 | 5.8 |
| U.S. | 42.9 | 6.5 |

As expected, Herfindahl-Hirschman indexes are strongly correlated to the four country concentration rate (Spearman's rank correlation coefficient equals 0.967). According to the H index, Germany is the most diversified of the 16 core countries and Switzerland is the most concentrated. Canada and Australia share virtually the same four-country concentration rate but Canada appears to have a relatively more diversified pattern of immigrants when we extend the analysis to all the source countries. The U.S. has the median value of diversification according to both the four-country concentration rate and the H index.

Immigrant scientists were asked to evaluate the importance of fourteen possible reasons for coming to work in their current country of residence. Virtually no variation exists across country in response. The "opportunity to improve my future career prospects" and the presence of "outstanding faculty, colleagues or research team" trump all other reasons. (See Figure 1). "Excellence/prestige of the foreign institution in my area of research" and the "opportunity to extend my network of international relationships" tie for third place. Regardless of country, respondents list family reasons or fringe benefits last among reasons for coming to work in a foreign country.

**Figure 1 - Answers to question "How important was each of the following factors behind your choice to take a postdoc, employment or academic job in a country different than the one where you resided at age 18?" ranked by order of importance.**




## 4. Emigration

A strength of the GlobSci survey is that it not only provides information on immigrants working or studying in one of the 16 core countries but it also provides information on the percent of scientists living in a core country at age 18 who were working or studying in 2011 in a core country, be it the same or different. This information is summarized in the right hand panel (columns 4-8) of Table 2 for the 15,115 respondents who lived in a core country at age 18 and provided full and consistent information on international experience(s). Probability weights were used to compute the reported rates given that response rates varied by country.[9]

Once again we find considerable variation in the percent studying or working abroad. Not surprisingly, India heads the list with 39.8 percent of the scientists who lived there at age 18 working or studying in a different core country in 2011. But the country that has the second highest rate among the 16 is Switzerland, with approximately one third of its residents studying or working abroad in 2011. The Netherlands and the UK are next, with approximately one in

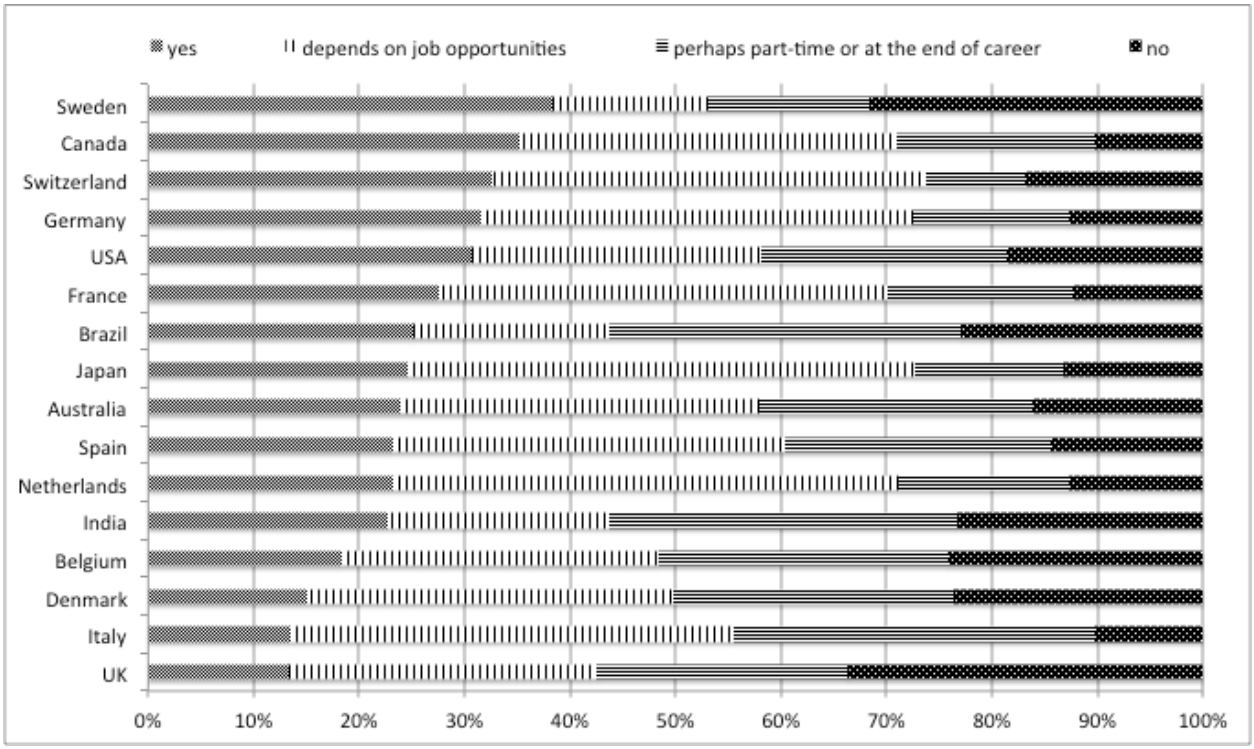
[9] The weights used are the inverse of the response rate of the country where the observation was collected and thus weight observations by the probability of inclusion in the sampling design. The logic is that response rates arguably depend more on factors existing in the country of residence at the time the survey was fielded rather than on nationality. Thus Italians living in Germany will have more similar response rates to French living in Germany than to Italians living in Italy. Examples of such country factors are settings on anti-spam filters, versions and settings of browsers, periods of the year when researchers are particularly busy, such as national holidays, vacations, exam periods, term breaks, etc.

four of their residents studying or working outside of country. The country with the lowest percent of emigrants is Japan (3.1 percent) but the United States is close to last at 5.0 percent, followed by Brazil and Spain.

There is considerably less variation in the country of destination (column 6). Indeed, the top destination country for emigrants from 13 of 15 countries is the United States; for the remaining two the United States is the second most likely destination country. The most likely destination country for individuals living in the United States at age 18 is Canada.

Migrants from Sweden and Canada are the most likely to report that they will return home at some time in the future, with more than one in three answering affirmatively (Figure 2) that they will, while less than one in five of the migrant scientists from the UK, Italy, Denmark and Belgium state that they plan to return at some time in the future. Indians working outside the country are less likely than the average emigrant to report that they plan to return. Close to one out of two emigrant scientists from the Netherlands and Japan see their return as conditional on job opportunities. Four out of ten scientists from five other countries (Italy, Spain, France, Germany and Switzerland) indicate that their return is conditional on job opportunities. Job prospects figure less importantly in the possible return for emigrants from other countries, with those from Sweden, Brazil and India placing the least emphasis on job prospects.

**Figure 2 - Answers to the question: "Is it possible that you return in the future?" by country of residency at age 18 in descending order of percent answering "yes".**




Information regarding the international experience of individuals living in one of the core countries at age 18 is provided in column 7 of Table 2. Particularly notable is the fact that half or more of the residents in 13 of the 16 countries have international experience. The rate is highest for Switzerland, followed closely by India where approximately three out of four natives have international experience. The country whose scientists have by far the lowest propensity for international experience is the United States. Table 2 also provides information on the percent with international experience who had returned to their country of origin by the time the survey was administered (column 8). Considerable variation exists, ranging from a high of 92 percent for emigrants from Japan to a low of 47 percent for India.

All respondents who indicated that they had studied or worked in a country different form their country of origin were asked whether or not they had subsequently returned. Those who had returned, were asked to rate the importance of the reasons behind their decision to return. The rating scale ranged from 1 to 5 with incremental steps of .1, where 1 was "totally

unimportant" and 5 was "extremely important." Average scores assigned by returnees to each of the motivations by country of origin (and return) are reported in Table 4.

**Table 4 - How important was each of the following reasons behind your decision to return to the country where you lived when you were 18. Average score.**

| Country of origin at 18 | excellence/ prestige of the institution in my area of research | outstanding faculty, colleagues or research team | better research infrastructures and facilities | greater availability of research funds | better wage / monetary compensation | better fringe benefits (parental leaves, pension, insurance, ..) | better working conditions (vacations, hours of work, ..) | opportunity to work with a specific group of scholars or colleagues | better job opportunity or career prospects | better quality of life | personal or family reasons | visa or immigration reasons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 3.1 | 3.1 | 2.8 | 2.6 | 2.9 | 2.7 | 2.8 | 2.9 | 3.2 | 4.1 | 4.3 | 1.9 |
| Belgium | 2.8 | 2.9 | 2.6 | 2.5 | 2.4 | 2.9 | 2.8 | 3.3 | 3.4 | 3.5 | 4.4 | 1.8 |
| Brazil | 3.1 | 3.0 | 2.4 | 2.6 | 2.7 | 2.6 | 2.6 | 2.9 | 3.3 | 3.3 | 4.1 | 1.9 |
| Canada | 3.3 | 3.3 | 2.9 | 2.9 | 2.8 | 3.2 | 2.9 | 2.9 | 3.4 | 3.9 | 4.1 | 1.6 |
| Denmark | 2.8 | 3.1 | 2.7 | 2.7 | 2.8 | 3.1 | 3.1 | 2.8 | 3.1 | 3.5 | 4.5 | 1.3 |
| France | 3.4 | 3.4 | 2.8 | 2.4 | 2.2 | 3.6 | 3.3 | 3.4 | 3.4 | 3.8 | 4.2 | 1.5 |
| Germany | 3.4 | 3.5 | 3.2 | 3.3 | 2.8 | 3.1 | 2.7 | 3.2 | 3.6 | 3.3 | 4.0 | 1.6 |
| India | 4.0 | 3.5 | 3.3 | 3.3 | 2.8 | 3.0 | 3.1 | 3.1 | 3.4 | 3.3 | 4.1 | 2.1 |
| Italy | 2.6 | 2.6 | 1.9 | 1.8 | 1.8 | 2.2 | 2.2 | 2.7 | 2.6 | 3.2 | 4.3 | 1.4 |
| Japan | 3.2 | 3.2 | 3.3 | 3.1 | 3.0 | 2.8 | 2.7 | 3.2 | 3.6 | 3.2 | 3.7 | 2.0 |
| Netherlands | 2.9 | 3.1 | 2.8 | 2.6 | 2.6 | 2.6 | 2.6 | 2.9 | 3.3 | 3.1 | 4.1 | 1.6 |
| Spain | 2.8 | 3.0 | 2.3 | 2.3 | 2.3 | 2.6 | 2.6 | 3.0 | 3.4 | 3.7 | 4.5 | 1.4 |
| Sweden | 2.8 | 2.8 | 2.7 | 2.9 | 2.4 | 3.5 | 3.2 | 2.7 | 3.0 | 3.7 | 4.5 | 1.5 |
| Switzerland | 3.6 | 3.6 | 3.7 | 3.7 | 3.6 | 3.1 | 2.8 | 3.3 | 3.6 | 3.8 | 4.3 | 1.5 |
| UK | 3.6 | 3.5 | 2.9 | 2.9 | 2.4 | 2.5 | 2.6 | 3.2 | 3.4 | 2.9 | 3.9 | 1.8 |
| U.S. | 3.6 | 3.6 | 3.5 | 3.4 | 3.1 | 2.7 | 2.4 | 3.1 | 3.8 | 2.9 | 3.9 | 1.8 |
| AVERAGE | 3.3 | 3.3 | 2.9 | 2.8 | 2.6 | 2.9 | 2.7 | 3.1 | 3.4 | 3.4 | 4.1 | 1.7 |

Table 5 reports the percent that rated as "important" or "very important" the same motivations. Regardless of country, the most likely reason scientists give for returning to their country of origin is for "personal or family reasons" and "personal and family reasons" are most likely to be scored "important" or "very important."

**Table 5 - How important was each of the following reasons behind your decision to return to the country where you lived when you were 18. Percent indicating "important" or "extremely important".**

| Country of origin at 18 | excellence/ prestige of the institution in my area of research | outstanding faculty, colleagues or research team | better research infrastructures and facilities | greater availability of research funds | better wage / monetary compensation | better fringe benefits (parental leaves, pension, insurance, ..) | better working conditions (vacations, hours of work, ..) | opportunity to work with a specific group of scholars or colleagues | better job opportunity or career prospects | better quality of life | personal or family reasons | visa or immigration reasons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 33.6 | 27.9 | 15.6 | 11.6 | 23.3 | 26.0 | 22.4 | 27.0 | 35.7 | 68.4 | 83.3 | 6.4 |
| Belgium | 20.4 | 20.4 | 12.6 | 9.6 | 7.3 | 29.0 | 17.9 | 41.6 | 47.5 | 45.0 | 86.0 | 7.3 |
| Brazil | 40.9 | 34.9 | 13.6 | 22.4 | 22.6 | 22.2 | 19.1 | 29.1 | 42.8 | 46.0 | 75.4 | 12.0 |
| Canada | 43.0 | 40.6 | 21.5 | 23.4 | 22.6 | 40.2 | 28.0 | 25.7 | 44.3 | 66.5 | 73.4 | 5.5 |
| Denmark | 22.7 | 35.0 | 22.2 | 22.7 | 19.5 | 39.3 | 43.3 | 20.1 | 38.9 | 44.9 | 91.5 | 3.5 |
| France | 41.6 | 41.0 | 17.2 | 8.4 | 8.0 | 53.6 | 38.1 | 45.1 | 44.9 | 60.8 | 80.4 | 5.0 |
| Germany | 48.1 | 49.8 | 36.1 | 39.8 | 19.3 | 34.0 | 19.1 | 36.3 | 49.6 | 38.2 | 72.2 | 7.6 |
| India | 67.2 | 49.9 | 35.6 | 39.5 | 19.6 | 24.8 | 27.8 | 32.0 | 39.1 | 34.9 | 70.8 | 14.3 |
| Italy | 20.7 | 22.0 | 5.2 | 5.5 | 4.8 | 11.4 | 8.5 | 27.0 | 23.8 | 37.6 | 82.2 | 1.9 |
| Japan | 34.9 | 31.6 | 38.8 | 27.8 | 24.8 | 16.7 | 14.7 | 35.1 | 52.1 | 32.5 | 59.2 | 9.7 |
| Netherlands | 22.7 | 28.3 | 19.0 | 15.6 | 17.8 | 17.7 | 16.6 | 27.2 | 45.7 | 37.4 | 75.1 | 7.2 |
| Spain | 22.5 | 31.0 | 7.2 | 7.5 | 8.5 | 16.8 | 14.9 | 31.3 | 45.2 | 57.8 | 87.9 | 2.9 |
| Sweden | 23.8 | 21.8 | 22.8 | 23.1 | 6.4 | 48.1 | 32.4 | 22.7 | 26.3 | 52.4 | 87.5 | 1.3 |
| Switzerland | 55.6 | 52.3 | 56.6 | 56.8 | 50.4 | 35.7 | 18.8 | 42.2 | 48.7 | 60.7 | 82.7 | 3.2 |
| UK | 49.7 | 43.8 | 19.8 | 18.8 | 8.5 | 11.5 | 14.8 | 36.2 | 43.0 | 19.6 | 65.8 | 11.2 |
| U.S. | 56.6 | 53.9 | 50.4 | 44.9 | 36.1 | 20.6 | 13.3 | 34.2 | 62.6 | 24.3 | 66.2 | 10.7 |
| AVERAGE | 40.5 | 38.9 | 25.9 | 23.9 | 18.1 | 26.8 | 20.4 | 33.9 | 45.3 | 43.5 | 74.5 | 7.5 |

## 5. Discussion/Conclusion

The GlobSci survey is the first comprehensive study of mobility patterns of scientists actively engaged in research in a large number of countries. The survey finds a high rate of foreign-raised talent studying and working in a number of countries. To put it bluntly, the United States is not that atypical when it comes to a strong reliance on foreign talent. But there are a number of countries—including India, Italy, Japan, Brazil and Spain—where foreign scientists and engineers are extremely rare. The survey also finds considerable variation in emigration patterns across countries. Swiss and Indian scientists are the most mobile; those from

the United States the least mobile. The survey also documents that, for virtually all the core countries studied, the United States is the dominant destination country.

Policy levers appear to be extremely important in attracting scientists to work or study abroad. Regardless of country, opportunities to improve one's future or the availability of outstanding faculty, colleagues or research teams prove the most important reasons for immigration. But policy levers appear to have played little role in pulling returning emigrants back to their home country. For these returnees, and regardless of country, "personal or family reasons" are the most important factor influencing the decision to return. It does not follow, however, that countries have no ability to influence the return decisions of emigrants living abroad. As noted above, emigrant scientists from a handful of countries report that whether or not they return in the future will depend in part on job market conditions.

GlobSci is not without limitations. First, it is restricted to researchers who have published in one of 16 countries. Second it is limited to four fields of science. Third, due to problems encountered in administering the survey, China was excluded from the core countries studied. Fourth, GlobSci provides but a snapshot of scientists active in 2009, thereby limiting the ability to compare cohorts of scientists overtime. Despite these limitations, GlobSci represents the largest international survey of scientists working in these four fields at this time.

# APPENDIX

## A1.Sampling procedure

We surveyed active researchers in the four scientific disciplines of biology, chemistry, earth and environmental sciences, and materials science during the period February-June 2011.

In constructing the sample, we selected all journals classified by ISI as belonging to one of the four disciplinary fields and sorted them by Impact Factor for all subfields of the four disciplines. Impact Factor was taken from the latest available release of the Journal Citation Report of Thomson-Web of Science®. We then randomly picked a selection of four journals in each quartile of the Impact Factor distribution in each subfield of each of the four disciplines. In the aggregate, this selection corresponds to approximately 30% of all journals published in the four fields.

We downloaded full references of all scientific articles published in the selected journals in 2009 and retrieved the email address of the corresponding author. In case of multiple corresponding authors, we picked the first name on the list. In the case of corresponding authors appearing repeatedly in the list, we randomly selected one record.

We coded the records by country, based on the domain name of the email address (e.g. ".au" for Australia; ".be" for Belgium, etc.). We identified U.S. authors by those having ".edu" in the address, thereby restricting the U.S. sample to academic researchers. Surveyed countries are: Australia, Belgium, Brazil, Canada, Denmark, France, Germany, India, Italy, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom, United States. China was initially included in the survey. However, a low response rate of less than 5 percent for a test sample of Chinese addresses suggested that respondents were either not receiving the invitation or had problems responding to the invitation. We thus decided not to survey researchers based in China.

**Table A- 1 - Sixteen country panels by scientific discipline**

| Core country | Biology | Chemistry | Earth | Materials Science | Total |
|---|---|---|---|---|---|
| Australia | 470 | 386 | 490 | 225 | 1571 |
| Belgium | 253 | 214 | 131 | 108 | 706 |
| Brazil | 626 | 473 | 161 | 277 | 1,537 |
| Canada | 825 | 685 | 621 | 324 | 2,455 |
| Denmark | 189 | 170 | 99 | 55 | 513 |
| France | 1,026 | 1,380 | 671 | 762 | 3,839 |
| Germany | 1,303 | 1,533 | 763 | 781 | 4,380 |
| India | 282 | 587 | 160 | 351 | 1,380 |
| Italy | 771 | 1,097 | 514 | 397 | 2,779 |
| Japan | 1,485 | 1,996 | 562 | 1,207 | 5,250 |
| Netherlands | 382 | 275 | 223 | 156 | 1,036 |
| Spain | 620 | 939 | 369 | 375 | 2,303 |
| Sweden | 326 | 251 | 181 | 124 | 882 |
| Switzerland | 285 | 265 | 256 | 113 | 919 |
| UK | 1,312 | 1,051 | 748 | 584 | 3,695 |
| U.S. | 5,135 | 4,247 | 2,667 | 2,010 | 14,059 |
| Total | 15,290 | 15,549 | 8,616 | 7,849 | 47,304 |

The procedure produced a sample of unique article-corresponding author addresses of 47,304 scientists in 16 countries. The country panel sizes are highly variable. The smallest panel is Belgium (706) and the largest is the U.S. (14,059), reflecting differentials in country contributions to scientific publications. Table A- 1 provides summary statistics on the panel of invited respondents by country and scientific discipline.

We track two characteristics of the articles from which the email of the corresponding author was extracted: number of coauthors of the article and total citations received by the article as of February 2010 (Table A- 2). The latter are retrieved from the Thomson-Web of Science® database. Variability across countries reflects field differences as well as variation in the quality of research being performed within country. The Swiss sample is associated with articles having the highest number of citations; the Brazilian sample is associated with articles having the lowest number.

**Table A- 2 - Characteristics of the panels: total cites and number of co-authors**

| Core country | Total Cites* | Number of coauthors |
|---|---|---|
| Australia | 0.95 | 4.61 |
| Belgium | 0.97 | 5.85 |
| Brazil | 0.39 | 5.27 |
| Canada | 0.85 | 4.33 |
| Denmark | 1.08 | 4.83 |
| France | 0.91 | 5.54 |
| Germany | 1.17 | 5.10 |
| India | 0.46 | 3.68 |
| Italy | 0.67 | 5.74 |
| Japan | 0.77 | 5.26 |
| Netherlands | 1.11 | 5.27 |
| Spain | 0.74 | 4.98 |
| Sweden | 1.01 | 4.88 |
| Switzerland | 1.55 | 5.14 |
| UK | 1.23 | 4.95 |
| U.S. | 1.31 | 4.64 |

*Cumulated as of February 2010.

### A2. Survey administration and questionnaire

The main language of the survey is English. However, the questionnaire and the invitation emails were available in six other languages: French, German, Italian, Japanese, Portuguese and Spanish. The online questionnaire was developed through the platform Qualtrics® that supports multiple languages. The survey administrator chose a primary language to use in emails and set the list of languages available for a specific country survey. The platform then automatically deploys the language in which the recipient has set her browser, and lets the respondent switch from one language to another at any point while filling-in the questionnaire.

Table A- 3 reports the languages used to administer the survey by country. Each panel member was emailed at most three times during February-June 2011 and asked to complete the web-based questionnaire. The platform recorded partial answers, allowing respondents to follow-up in additional rounds. The U.S. sample was divided into three blocks, due to the size of the sample. The questionnaire is available at http://www.dig.polimi.it/uploads/media/GlobSci_survey.pdf.

**Table A- 3 - Primary and secondary languages in which the survey was administered**

| Core country | Primary languages | Secondary languages |
|---|---|---|
| Australia | English | - |
| Belgium | English | - |
| Brazil | Brazilian Portuguese | English |
| Canada | English, French | - |
| Denmark | English | - |
| France | French | English |
| Germany | German | English |
| India | English | - |
| Italy | Italian | English |
| Japan | Japanese | English |
| Netherlands | English | - |
| Spain | Spanish | English |
| Sweden | English | - |
| Switzerland | English | French, German, Italian |
| UK | English | - |
| U.S. | English | - |

### A3.Response rates

Table 1 in the text reports the number of answers received by country. Answers are further divided into complete answers and partial answers. The latter are answers from respondents who began the survey, but dropped-out before reaching the last question. The total dropout rate is 5 percent. The response rate is 40.6 percent if both complete and partial answers are counted; 35.6 percent if only complete answers are counted. As noted in the text, reported response rates do not take into account undelivered invitations due to such things as incorrect email address, retirement or death and consequently underestimate the response rate.

Response rates by scientific field are reported in Table A- 4. Participation was highest for scientists in earth and environmental sciences and lowest for scientists in biology.

**Table A- 4 - Response rates by scientific field**

| Scientific field | Panels | Total Answers | Of which complete | Of which dropouts | Total Response Rate % | Complete Response Rate % |
|---|---|---|---|---|---|---|
| Biology | 15,290 | 5,810 | 5,097 | 713 | 38.0 | 33.3 |
| Chemistry | 15,549 | 6,324 | 5,524 | 800 | 40.7 | 35.5 |
| Earth & Environment | 8,616 | 3,956 | 3,532 | 424 | 45.9 | 41.0 |
| Materials Science | 7,849 | 3,093 | 2,674 | 419 | 39.4 | 34.1 |
| Total | 47,304 | 19,183 | 16,827 | 2,356 | 40.6 | 35.6 |

**A4. Non-response bias**

We assess non-response bias along three dimensions. First, we compare early and late respondents; second, we compare respondents against non-respondents and third, we compare full-respondents against those who dropped-out. In all instances the comparison is done for two known characteristics for the entire panel and sample: total citations received by the underlying article and number of coauthors. Total citations arguably are positively correlated with the eminence of the scientist and could potentially reflect differentials in the propensity to answer related to how busy the respondent is. The number of co-authors is positively correlated with the amount of time it took to answer the questionnaire given that number of coauthors was a basis for a branching question in the survey. Therefore, the number of coauthors is potentially associated with dropping out of the survey. Tests for equality of means are performed for each pair of country samples.

Mean differences by country for early and late respondents are reported in Table A- 5. Early-respondents are those who completed the survey during the first and second round and late-respondents are those who completed the survey during third round. Regardless of country or measure, there is no significant difference at the 5 percent confidence level.

Comparison statistics for non-respondents vs. respondents are reported in Table A- 6. Authors of more highly-cited papers living in France, Italy, Spain and the U.S. are less likely to respond than those with lower-cited papers. Authors of papers with more co-authors living in Brazil, Germany, Italy and the U.S are also less likely to have answered.

**Table A- 5 - Two-groups comparisons. T-Tests. Hypothesized difference (early respondents – late respondents)=0**

| Core country | Total Cites | Number of authors |
|---|---|---|
| | mean diff. (st. err.) | mean diff. (st. err.) |
| Australia | 0.174 | -0.393 |
| | (0.200) | (0.287) |
| Belgium | -0.084 | 0.575 |
| | (0.329) | (0.450) |
| Brazil | 0.148 | 0.144 |
| | (0.083) | (0.227) |
| Canada | -0.208 | -0.372 |
| | (0.132) | (0.219) |
| Denmark | 0.192 | -0.367 |
| | (0.481) | (0.519) |
| France | 0.047 | -0.167 |
| | (0.133) | (0.216) |
| Germany | -0.140 | -0.042 |
| | (0.221) | (0.238) |
| India | -0.093 | 0.119 |
| | (0.117) | (0.217) |
| Italy | -0.049 | -0.334 |
| | (0.117) | (0.230) |
| Japan | 0.151 | -0.060 |
| | (0.157) | (0.241) |
| Netherlands | 0.045 | 0.250 |
| | (0.254) | (0.364) |
| Spain | -0.099 | -0.040 |
| | (0.138) | (0.203) |
| Sweden | -0.123 | -0.531 |
| | (0.317) | (0.448) |
| Switzerland | -0.297 | -0.357 |
| | (0.438) | (0.438) |
| UK | 0.165 | 0.173 |
| | (0.182) | (0.235) |
| U.S. | 0.199 | 0.074 |
| | (0.106) | (0.102) |

*p<0.05

**Table A- 6 Two-groups comparisons. T-Tests. Hypothesized difference (non-respondent – respondent)=0**

| Core country | Total Cites | Number of authors |
|---|---|---|
| | mean diff. (st. err.) | mean diff. (st. err.) |
| Australia | -0.039 | 0.035 |
| | (0.098) | (0.142) |
| Belgium | -0.268 | -0.274 |
| | (0.162) | (0.222) |
| Brazil | 0.088 | 0.397 |
| | (0.046) | (0.125)* |
| Canada | 0.009 | 0.160 |
| | (0.063) | (0.105) |
| Denmark | -0.002 | -0.114 |
| | (0.224) | (0.242) |
| France | 0.122 | 0.029 |
| | (0.058)* | (0.094) |
| Germany | 0.158 | 0.205 |
| | (0.092) | (0.099)* |
| India | 0.029 | 0.008 |
| | (0.052) | (0.096) |
| Italy | 0.181 | 0.288 |
| | (0.061)* | (0.120)* |
| Japan | 0.089 | 0.112 |
| | (0.052) | (0.080) |
| Netherlands | 0.069 | 0.031 |
| | (0.124) | (0.178) |
| Spain | 0.161 | 0.051 |
| | (0.064)* | (0.095) |
| Sweden | -0.040 | 0.089 |
| | (0.133) | (0.188) |
| Switzerland | 0.212 | 0.206 |
| | (0.200) | (0.200) |
| UK | 0.143 | 0.123 |
| | (0.083) | (0.108) |
| U.S. | 0.354 | 0.146 |
| | (0.052)* | (0.049)* |

*p<0.05

Results of test comparisons for full-respondents against partial respondents (dropouts) are reported in Table A- 7. Results indicate that more cited authors from Belgium were more likely to dropout. The opposite is true for more cited authors from India, who were more likely than less-cited authors to take the survey in full. Dutch authors with more coauthors are also more likely to have completed the survey in full.

**Table A- 7 - Two-groups comparisons. T-Tests. Hypothesized difference (complete – dropout)=0**

| Core country | Total Cites | Number of authors |
|---|---|---|
| | mean diff. (st.err.) | mean diff. (st.err.) |
| Australia | -0.162 | -0.637 |
| | (0.224) | (0.371) |
| Belgium | -0.962 | -0.120 |
| | (0.405)* | (0.463) |
| Brazil | -0.065 | -0.298 |
| | (0.104) | (0.299) |
| Canada | 0.168 | -0.257 |
| | (0.150) | (0.242) |
| Denmark | 0.029 | -0.293 |
| | (0.670) | (0.650) |
| France | 0.192 | 0.278 |
| | (0.122) | (0.197) |
| Germany | -0.096 | -0.387 |
| | (0.207) | (0.236) |
| India | 0.196 | 0.064 |
| | (0.084)* | (0.175) |
| Italy | -0.069 | -0.417 |
| | (0.105) | (0.239) |
| Japan | 0.176 | 0.079 |
| | (0.144) | (0.214) |
| Netherlands | 0.565 | 0.872 |
| | (0.290) | (0.438)* |
| Spain | 0.111 | -0.068 |
| | (0.117) | (0.192) |
| Sweden | 0.401 | -0.161 |
| | (0.300) | (0.387) |
| Switzerland | -0.832 | -0.479 |
| | (0.517) | (0.455) |
| UK | 0.015 | -0.063 |
| | (0.175) | (0.282) |
| U.S. | -0.130 | 0.105 |
| | (0.101) | (0.118) |

* $p<0.05$

## REFERENCES


Auriol, Laudeline (2010) "Careers of Doctorate holders: employment and mobility patterns" OECD STI Working paper 2010/4

_____ (2007) "Labour market characteristics and international mobility of doctorate holders: results for seven countries" OECD STI Working papers 2007/2.

Empirica GmbH (2005) "Post-Docs in the Life Science" Paper prepared for the NetReAct project. Dowloadable at: www.netreact-eu.org/documents/NetreactDeliverable1.3.pdf

Haeussler, Carolin (2011). "Information Sharing in Academe and Industry: A Comparative Study," *Research Policy*. 40:105-122. (2011).

Hirschman, Albert O. (1964). "The Paternity of an Index." *The American Economic Review* 54(5):761, (1964).

Hunter, Rosalind S., Andrew J. Oswald and Bruce Charlton. 2009. "The Elite Brain Drain." *Economic Journal* 119:231-251.

Levin, Sharon and Paula Stephan. (1999). "Are the Foreign Born a Source of Strength for U.S. Science?" *Science* 285:1213-14.

MORE (2011) "Mobility and career paths Of Researchers in Europe" Project funded by the European Commission (DG Research) and carried out by a consortium of international organisations led by IDEA Consult. http://www.researchersmobility.eu

National Science Board. (2012), *Science and Engineering Indicators: 2012*. Arlington, VA: National Science Foundation.

Sauermann, Henry, and Mike Roach (2011a). "Not all scientists pay to be scientists: Heterogeneous preferences for publishing in industrial research," Georgia Institute of Technology, working paper (2010).

_____(2011b). "Static and Dynamic Drivers of Web Survey Response Rates: An Experimental Study. Georgia Institute of Technology, working paper.

SCImago Journal and Country Rank database. Retrieved April 28, 2010, from http://www.scimagojr.com/

Stephan, Paula (2012). *How Economics Shapes Science*, Cambridge, MA: Harvard University Press.

Walsh, John, Wes Cohen, and Charlene Cho. (2007). "Where Excludability Matters: Material versus Intellectual Property in Academic Biomedical Research." *Research Policy* 36:1184-203.