Migrant Scientists and International Networks: Diaspora and Home Country Advantage

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Abstract

We examine collaboration patterns of foreign scientists working in one of 16 countries in 2011 and compare them to the collaboration patterns of nonmigrant scientists and scientists with some international experience who have returned to their home country. Data come from the GlobSci survey. In addition we analyze the collaboration patterns of Korean scientists working in the United States and compare these patterns to collaboration patterns of migrants in general and from China in particular. Major findings are that both foreign-born scientists and returnees have larger international research networks than do native researchers who lack an international background. The higher incidence of international collaboration among migrants is driven primarily by those who did not get their BA or PhD training in the destination country but rather came for a postdoctoral position or directly for employment. We also find that a sizeable share of the foreign born collaborate with researchers located in their country of origin and that migrants are also likely to collaborate with individuals from their home country who are working or studying in a third country (diaspora effect). We find the size of the international networks of Koreans studying or working in the US to be smaller than that of other emigrants. A plausible cause is that the majority of Koreans in the US initially came for either undergraduate or graduate training. On the other hand, we find Koreans located in the US to be just as likely to have coauathored a paper with someone in their home country than other respondents to the survey. Given that the stay rate for Korean PhD recipients in the US is increasing, our results suggest that it may be beneficial for the Korean government to implement programs that enhance collaboration between emigrants and scientists based in Korea.

I. Introduction

Scientists are increasingly mobile between countries. They move for study and for work. Many stay; others eventually return to their home country while others go to a third country and/or have repeated bouts of mobility. Countries often encourage mobility by providing fellowships for students to go abroad for study or for early career scientists to work abroad. Countries also encourage emigrants to return home, providing incentives, such as career enhancements for those returning. Likewise, countries encourage immigration of highly-skilled workers, through programs such as visa policies based on skill, or by providing support for international students and postdoctoral scholars to study or work in country.

There is considerable evidence that the foreign born contribute to innovation ((Hunt, 2011) (Kerr, 2013)). There is some evidence that they contribute disproportionately to innovation ((Stephan & Levin, Exceptional Contributions to US Science bgy the Foreign-born and Foreign-educated, 2001); (Franzoni, Scellato, & Stephan, 2014). Recent evidence also suggests that ethnically diverse teams, many of whose members are immigrants, produce more highly cited papers than less ethnically diverse teams (Freeman & Huang, 2014) and there is some evidence that international collaboration leads to research of a higher quality (Franzoni, Scellato, & Stephan, 2014)). There is also evidence to suggest that returnees author papers of a higher quality than their compatriots who have never studied or worked abroad (Franzoni, Scellato, & Stephan, 2014). But less is known about the extent to which the country of origin benefits from research that emigrants engage in abroad. This is a particular concern to countries that are major exporters of talent that has a high propensity to stay in the country of immigration. The question is of critical importance given that "the development and dissemination of knowledge is," to quote Richard Freeman, "the one ring that rules all else in modern economic development."[1]

The United States benefits substantially from foreign-born talent. At a minimum, a quarter of faculty in science and engineering were not citizens at the time they received their PhD degree—whether the degree was received in the United States or outside the United States (Stephan, 2012). More than four out of ten PhD recipients in science and engineering (excluding the social sciences and psychology) are foreign born. More than six out of ten postdocs working in the United States were born outside the country and many of these received their PhD outside the country (Stephan, 2012).

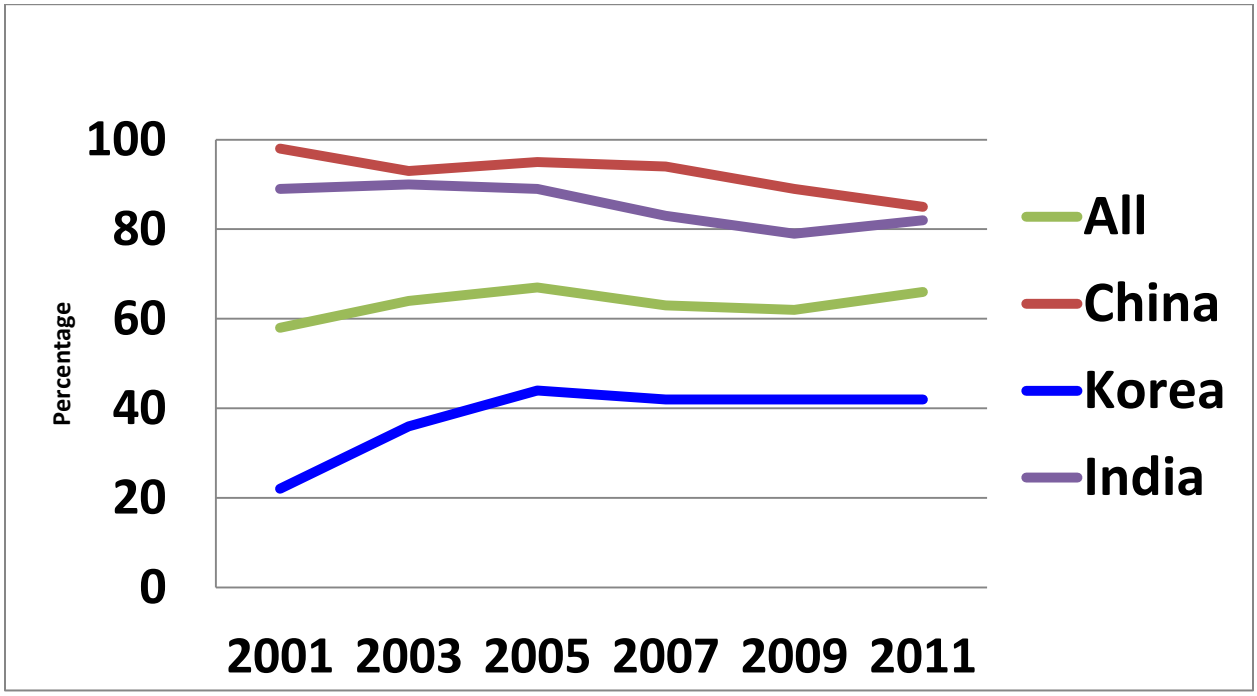
This paper contributes to our understanding of the contributions of the foreign to both the host country and to the home country by examining the extent to which foreign scientists collaborate with individuals living outside their country of current residence and comparing these patterns of collaboration to those of nonmigrant scientists and scientists with some international experience who have returned. We are

[1] Richard Freeman, presentation at the "High-Skilled Immigration Policy and the Competition for Talent" workshop, National Academies of Science, Keck Center, Washington, DC., September 22, 2014. Freeman argues that to the extent there is a second ring, it is international trade. He points out that it is hard to do a valid counterfactual. See (Freeman, 2013)

especially interested in the extent to which foreign scientists collaborate with scientists living in their home country given the positive spillovers that such collaborations have for the country of origin. Data for the study come from the GlobSci survey of 47,000 plus scientists working or studying in 16 countries in 2011.

Part of our research focuses on immigrant scientists working or studying in the United States and the extent to which this large foreign-born group has international collaborators. Such analysis is particularly relevant for the countries of China, India and Korea given that more than 50 percent of all US foreign PhD recipients come from one of these three (Stephan, 2012). Among these three, recipients from China and India historically have had an extremely high propensity to stay on in the US after training. The five-year stay rate, for example, for the Chinese has historically been above 90 percent and only began to fall after the Crisis of 2008. That of India has historically been above 85 percent (Finn, 2014). In this respect, Korea differs considerably from the others (Finn, 2014). In 2001, for example the five-year stay rate was only 22 percent. But the rate doubled between 2001 and 2005, going up to 44 percent and is currently only marginally lower.[2] Thus the extent to which Koreans working or studying in the United States form international collaborations is increasingly relevant for the country of Korea (Figure 1.)

Figure 1—Five-Year Stay Rates for Foreign Students on Temporary Visas Receiving Science and Engineering Doctorates in US, Selected Countries, 2001-2011 (Finn, 2014)



[2] Finn did not compute stay rates by country before 2001.

The plan of this paper is as follows: In section II we briefly summarize the literature relating to collaboration. Section III provides an overview of the survey methodology. In Section IV we compare collaboration patterns between immigrants and nonimmigrants as well as returnees. Section V presents estimates of probit models where the dependent variable is a discrete measure of the network size. Similar equations are estimated exclusively for the United States and Korean migrants are distinguished from other migrants. Conclusions are drawn in section VI.

II. Mobility and International Networks

A fact known with considerable certainty is that research is increasingly a collaborative effort: research teams are becoming larger and a growing proportion of teams are composed of scientists based at different institutions and in different countries ((Wuchty, Jones, & Uzzi, 2007) (Jones, Wuchty, & Uzzi, 2008) (Gazni, Sugimoto, & Didegah, 2012)). It has been estimated that in the first decade of this century, international collaborations grew from 14 percent of all publications in ISI Web of Science in 2000 to 18 percent in 2009. The increase occurred in all scientific fields, with the exception of physics, which was already extremely international and occurred largely among teams of three or more co-authors (Gazni, Sugimoto, & Didegah, 2012). There is evidence that this increase started as early as the 1980s. For example in the US, the foreign-share of papers with an international collaborator increased steadily from about 5.1 percent per year during the 1980s to about 7.4 percent during the 1990s, with the increase being driven primarily by collaborations with Asian and European institutions (Adams, Black, Clemmons, & Stephan, 2005). The share of European papers co-authored with US-based researchers increased from 5.9 percent in 1985 to 9.5 percent in 1995, while papers co-authored with Japan-based researchers increased from 0.5 percent to 1.3 percent and those with researchers based in Canada from 0.9 percent to 1.6 percent (Georghiou, 1998).

We also know that the rate at which the tertiary educated are internationally mobile has increased during the same decades at a high pace and that a large proportion of highly-educated migrants circulates among relatively wealthy countries (Docquier, Lowell, & Marfouk, 2009). In light of this evidence, it is somewhat puzzling that migration has been left in the background, if mentioned at all, in the literature that has discussed reasons behind increased international collaborations ((Katz & Martin, 1997) (Georghiou, 1998) (Gazni, Sugimoto, & Didegah, 2012)). Instead, prior studies have examined the extent to which the increase in collaboration has been enabled by the advent of emails and inexpensive international communication ((Ding, Levin, Stephan, & Winkler, 2010) (Winkler, Glanzel, Levin, & Stephan, 2014)); by mechanisms of preferential attachment that researchers develop to gain reputation and visibility (Wagner & Leydesdorff, 2005); by the increase of bilateral research agreements, especially with regard to big science projects (Georghiou, 1998); and as a result of the widespread use of funding schemas that mandate cross-country collaboration in the European area (Defazio, Lockett, & Wright, 2009). This gap in research linking increased collaboration to increased mobility likely stems from a lack of consistent data on scientists working in multiple countries.

The GlobSci data allow us to address this gap. A first objective of our research, therefore, is to investigate the understudied link between migration and network formation and to provide evidence

regarding the extent to which mobility is a likely engine of international research collaboration. Due to the structure of our data, we cannot claim to observe a causal relation between mobility and network formation. To the extent that migration happens because of international collaborations among teams, this relationship may indeed go the opposite way. Moreover, we do not have longitudinal data and thus cannot observe changing patterns over time. Nonetheless, we take a first step by examining the proportion of research conducted in international teams that involves investigators who had a prior experience of work or study in a different country and compare the extent to which domestic and foreign-born scientists differ in their propensity to be involved in international teams.

A strength of our study is that our measures of international collaboration do not rely exclusively on co-authorship patterns. Although the latter provide a reasonable proxy of scientific collaborations, and one largely used by scholars, there are several well-known limitations to this approach (Katz & Martin, 1997). One limitation is that co-authorships capture only the formal and most visible part of collaborations, overlooking informal collaborations, the so-called "invisible colleges" ((de Solla Price, 1963); (Crane, 1972)), that may not result in joint authorship, but are nonetheless extremely relevant in explaining the progress and dissemination of scientific knowledge. A second limitation is that publication databases, such as ISI, are known to be biased in favor of English-language journals and are therefore prone to undercount collaborations occurring among countries with a substantial corpus of publications in national language, such as China, Korea and Japan.

Our data also allow us to qualify the collaboration based on several characteristics of the scientist. One characteristic of interest in this paper is whether the scientist is foreign born and, if she is, the point in the career that she migrated to the country of destination. We are particularly interested in seeing whether the alleged advantage the foreign born hold in establishing international collaborations varies depending on the intensity of the social connections with the scholarly community that existed at the time of entry into the foreign country. Prior research has documented the relevance and endurance of social relationships that people keep with individuals who were formerly co-located (Saxenian, 1994); (Almeida & Kogut, 1999). Agrawal, Cockburn and McHale (Agrawal, Cockburn, & McHale, 2006) document this relationship at the individual level, by studying inventors who move from one company to another and show that movers disproportionally cite colleagues at their prior location. They explain the finding by suggesting that even though such inventors could no longer benefit from frequent informal discussions and casual meetings among co-workers in the same geographic location, social relationships forged when they worked together facilitate the transmission of knowledge across long distances, in the spirit of the spread of "intellectual innovations" that happens in invisible colleges (Crane, 1972).

We expect that the extent to which social relations are likely to endure and facilitate collaboration depends on the knowledge and expertise of the people involved. Therefore one condition that enhances knowledge transmission should be that the mover is acquainted with colleague-scholars at the time he or she migrates. Moreover, one would expect the effect to be stronger, the stronger the science base in the country of origin. To the extent that a senior scientist has more social capital with other scientists than a junior scholar and a junior scholar has more social capital with other scholars than does an early

trainee, we would expect to observe variation in the degree to which the timing of entry in terms of career stage to the destination country is associated with international network formation. A second contribution of this paper, therefore, is to investigate if the size of a migrant's international network depends upon the scientist's career stage at the time the scientist departed the home country.

Another contribution of this paper is to investigate the importance of national ties in forming international collaborations. Prior research conducted on inventors has documented the existence of "ethnic communities" ((Kerr W. , 2008) (Agrawal, Kapur, & J. McHale, 2011)), i.e. of working relationships among expats of the same country who live away from their home country and communicate either among each other or with people who remain in the home country. In this paper we measure the extent to which the international collaborations that the foreign-born maintain are likely to be explained by national links. We further distinguish between two types of national links: collaborations established with scholars based in the respondent's home country and collaborations established with same-nationals of the respondents who are expat in a third country. We refer to these latter as *diaspora networks*.

To the best of our knowledge, few prior studies have assessed the degree to which mobile scientists maintain relationships with their home country and virtually no study has assessed the relevance of diaspora networks in the international collaborations of scientists. With regard to the former, (Nagaoka, Igami, & Walsh, 2013) use two surveys of scientists administered in Japan and in the US and find that in both countries the odds of the research having international collaborators (as opposed to involving solely domestic collaborators) was larger for those articles whose corresponding author has had at least one year of research experience abroad. They make no distinction, however, regarding country of prior mobility of the corresponding author. Baruffaldi and Landoni (Baruffaldi & Landoni, 2013) analyze 497 scientists based either in Italy or in Portugal and find that more than half keep some sort of formal or informal link with their country of origin. They further find that keeping informal links with the origin country is associated with higher productivity. This and a few other studies have looked at the networking activities of the returnees to the home country, finding in general a positive association ((Jonkers & Tijssen) (Jonkers & Cruz-Castro, 2013)).

A final contribution of this research is to see if the patterns we observe differ between Korean emigrants vs. emigrants from other countries, and, to the extent to which differences exist, ferret out the reason for such differences.

III. GlobSci Survey

GlobSci was designed to provide consistent cross-country data on researchers. It surveyed 47,304 active researchers in the four scientific disciplines of biology, chemistry, earth and environmental sciences, and materials science working or studying in 16 countries during February-June 2011. Researchers were randomly selected on the basis of being a corresponding author of an article published in 2009 in a journal related to one of the four fields (referred to as the focal paper). Countries included are: Australia, Belgium, Brazil, Canada, Denmark, France, Germany, India, Italy, Japan, Netherlands, Spain,

Sweden, Switzerland, the United Kingdom, and the United States. In the subsequent sections we refer to this set of countries as "core." Collectively, the 16 core countries produce about 70 percent of all articles published in these fields.

Country of origin was determined by asking the respondents to report their country of residence at age 18.[3] International mobility was defined as being absent from one's country of origin for more than 12 months for purposes of study or work. Respondents residing in the same country as they did at age 18 are referred to as "natives;" those residing in a different country than where they lived at age 18 are referred to as "foreign born."

In order to construct the sample, all journals classified by the database ISI – Web of Science-- belonging to one of the four disciplinary fields were selected and then sorted 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 of the subfields of the four disciplines. In the aggregate, this selection corresponds to approximately 30 percent of all journals published in the four fields. Starting from these four lists of journals, we then downloaded full bibliographic data of all scientific articles published in the selected journals in 2009 and retrieved the email address of the corresponding authors of each of the survey articles. 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.[4] In order to build country panels, we coded these records, based on the final digits of the domain of the email address (e.g. ".au" for Australia; ".be" for Belgium, etc.). We identified US authors by those having ".edu" in the address, thereby restricting the US sample to academic researchers.

Panelists were invited to participate by email. The invitation letter and survey was fielded in English. Both the invitation letter and the survey instrument were available in six additional languages. The overall response rate is 40.6 percent. The response rate, conditional on completing the survey, is 35.6 percent.[5] Response rate bias is discussed in Supporting Information in (Franzoni, Scellato, & Stephan,

[3] We prefer to use country of residence at age 18 to country of birth because we are interested in mobility decisions occurring for reasons of work or study of the respondents. Relocation events occurring before the age of 18 likely reflect parental decisions rather than choices of the respondent. We have also collected data on country of birth and migration activity before age 18. We use information regarding international mobility during childhood as a control for endogenity of mobility and research performance in (Franzoni, Scellato, & Stephan, 2014). We exploit migration during childhood also in this paper to control for possible endogenity biases in a specific model specification.

[4] In the four selected fields 95 percent or more of all articles contain an email address for the corresponding author. More specifically, in 2009 the estimated number of records that did not report email address for corresponding author was 0.9 percent in biology, 3.6 percent in chemistry, 2.9 percent in earth and environmental sciences and 4.5 percent in materials science.

[5] Most web-based surveys have a response rate of 10-25 percent (Sauermann & Roach, 2013). Our 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 of those receiving invitations. Undelivered emails generally account for between 3 to 6 percent of a sample in the U.S. (Walsh, Cho, & Cohen, 2005) and (Sauermann & Roach, 2010).

2012). The sampling strategy and procedure is discussed in (Franzoni, Scellato, & Stephan, 2012) as well. 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 encountered somewhat similar problems in a later effort to survey scientists in Korea. Based on these test samples we discontinued our efforts to survey researchers living in China or Korea.

Data were collected regarding the survey article selected by the sampling criteria as well as information on background characteristics of the corresponding author. Concerning article-specific data, we collected information on whether the article involved an international collaboration and a set of reported characteristics of the topic that the survey article addresses (e.g. whether it is in an emerging or multidisciplinary field and whether it is in a main research area for the author). With regard to the corresponding author, we collected a number of individual characteristics, including age, gender, job position, type of affiliation, international mobility data (including current country, country of origin, reasons for leaving the origin country, periods of education or work abroad) and type of initial entry in the host country (for master/bachelor, PhD, Post-doc, direct employment). We also collected information from respondents on their international network of research collaboration. More specifically, we asked the respondent the number of countries in the last two years with which the respondent had collaborations. In the case of foreign-born respondents, we also asked whether they had collaborations with researchers still based in their origin country and/or with researchers from their origin country who had migrated to a third country.

IV. Summary Statistics

Slightly less than a quarter of the scientists in the GlobSci survey (23.1 percent) reported that they were currently studying or working in a country other than where they lived when they were 18. Here we refer to these scientists as “foreign born.” We refer to the 30 percent who had returned to their country of origin after one or more periods abroad for a PhD, a postdoc or employment, as “returnees.” The remainder (approximately 47 percent) are classified as “nonmobile.”

There is considerable variation in the percent of scientists who are foreign born across the 16 countries, as can be seen from Table 1. 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%), and then by the United States with 38.4% 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%, Japan with 5.0%, Brazil with 7.1% and Spain with 7.3%.

Table 1 - International mobility patterns of surveyed scientists by country of work or study in 2011.

Country of work or study in 2011	Incidence of foreign born (%)	Countries supplying 10% or more of foreign workforce
Australia	44.5	UK (21.1) China (12.5)
Belgium	18.2	Germany (15.2) France (15.2) Italy (13.0)
Brazil	7.1	Argentina (16.0) France (14.0) Columbia (12.0) Peru (12.0)
Canada	46.9	UK (13.5) U.S (13.5) China (10.9)
Denmark	21.8	Germany (24.4)
France	17.3	Italy (13.8)
Germany	23.2	None
India	0.8	*Data are not reported due to small numbers.*
Italy	3.0	France (13.0) Germany (11.1) Spain (11.1)
Japan	5.0	China (33.7) South Korea (11.6)
Netherlands	27.7	Germany (14.6) Italy (12.5)
Spain	7.3	Argentina (12.6) France (10.3) Italy (10.3)
Sweden	37.6	Germany (11.9) Russian Fed. (10.2)
Switzerland	56.7	Germany (36.9)
UK	32.9	Germany (15.2) Italy (10.4)
U.S.	38.4	China (16.9) India (12.3)

Source: Adapted from Franzoni et al. (2012) Foreign Born Scientists: Mobility Patterns for Sixteen Countries, Nature Biotechnology, 30(12) pp. 1250-1253.

Countries also vary in the degree of diversity of immigrants who work in country, measured by the percentage of immigrant researchers from the top source countries. Switzerland, which shows the highest incidence of foreign born, also has a very high concentration of inflows due to the substantial migration of researchers from Germany. Other countries, such as the UK, show a more diversified composition of source countries. The aggregated statistics reported above for the country level are computed using all collected observations for which information regarding country of origin and country of residence in 2011 was available.

Half of these immigrant scientists reported living in a non-core country at age 18. The greatest number were from China, followed by the Russian Federation, Korea, Argentina and Iran. The distribution by country of residence of the 61 scientists who resided in Korea at age 18 and were living in a core country in 2011 is given in Table 2. By far the largest percent reside in the United States, followed by Japan. Note that the data undercount mobile Korean scientists to the extent that they are working in a country not covered in the GlobSci survey, such as China.

Table 2 - Location in 2011 of Respondents residing in Korea at age 18: GlobSci Data

Current Country in 2011	Frequency	Percent
Japan	10	16.4
USA	45	73.8
Other countries	6	9.8
Total	61	100

Survey participants were asked to rate their perception of the impact of international mobility along a number of dimensions; a "5" represented extremely important; a "1" represented "totally unimportant." Summary statistics are provided in Table 3. On average, both returnees and foreign born researchers assigned the highest average value to the item "enlarging my research network", followed by "learning new techniques / theories". This is consistent with the hypothesis that international mobility has a non-negligible impact on the international openness of the research systems of both source and destination countries. The remainder of this chapter focuses on the relationship between mobility and participation in international networks.

Table 3 - The perceived impact of international mobility for returnees and foreign born.

	Returnees	Foreign born
Enlarging my research network	4.19	4.35
Establishing a stable research cooperation with teams/scholars located abroad	3.71	4.02
Entering into new fields of research	3.90	4.08
Learning new techniques/ theories	4.12	4.17
Improving my capability to publish in high-tiers journals	3.68	3.93
Improving my wage and earning possibilities	2.72	3.41
Improving my career prospects	3.89	4.08
Establishing better contacts with industrial partners	2.15	2.67
Improving my ability to raise research funds	3.16	3.65

Based on the survey data, we derive two measures of the individual's propensity to have an international research network using two alternative types of information: i) the number of countries with which the scientist reported having one or more collaborations in the past two years ii) characteristics of the survey paper in terms of whether it shows an international co-authorship.

Table 4 presents self-reported data concerning the number of countries with which the scientist reported having collaborations in the past two years. Data are also presented for the 54 Korean scientists living abroad who responded to the survey and the 491 Chinese living abroad.[6] Compared to the foreign born and to returnees, nonmobile researchers show on average the highest incidence of having no international collaboration or minimal international collaboration (with one country). Conversely, both foreign-born and returnees consistently show the highest incidence of collaboration with researchers in two or more countries. But these patterns do not characterize foreign-born Koreans in the sample who are almost two-and-a-half times more likely to have no international collaborations than the foreign born in general. Moreover, the collaborations they do have are small compared to those of other foreign born as well as others in the sample. The Koreans in the sample are also somewhat more likely than the Chinese to have no international collaborations or, if they do, small international collaborations: approximately sixty percent of the Koreans either do not engage in

[6] Note that the number is less than the 61 that were living outside of Korea because 7 individuals did not respond to this part of the survey.

international collaborations or collaborate with researchers in only one country compared to approximately fifty percent of the Chinese.

Table 4 - Size of the international research network related to the activities in the past two years by mobility status of respondents.

	Full Sample	Foreign born	Foreign Born-Koreans	Foreign Born Chinese	Returnees	Nonmigrant
No international collaborations	19.08	14.06	33.33	24.94	14.26	24.36
Small network (1 country)	18.71	17.59	27.78	24.46	17.28	19.91
Medium network (2 to 4 countries)	43.69	47.53	31.48	41.89	47.02	40.02
Large network (more than 4 countries)	18.53	20.82	7.41	8.72	21.45	15.72

Table 5 provides information regarding the incidence of international collaboration on the focal paper by mobility status. The data show that about 24 percent of the articles in our dataset involved an international collaboration. Articles co-authored by the foreign born are the most likely to have authors from more than one country; those co-authored by the nonmobile are least likely to have international coauthors. Once we look at nationality, however, we find that Koreans living abroad are more likely than other mobile researchers to have international coauthors on the focal paper and considerably more likely than the Chinese living abroad to have an international coauthor. This suggests that although the networks of Koreans are smaller, their propensity to write with one or more individuals outside the country of residence does not suffer from this smaller network size.

Table 5 - Incidence of internationally co-authored paper and mobility status of corresponding author

Full Sample	23.94
Foreign born, excluding Koreans and Chinese	33.19
Foreign born-Korean	39.62
Foreign-born Chinese	25.80
Returnees	29.12
Nonmigrants	20.26

Table 6 examines the incidence of collaboration with individuals from the home country among the foreign born and among Korean-foreign born and Chinese-foreign born. Because the largest percent of emigrant Koreans in our sample live in the US, the data are shown for those residing in the US as well as those residing anywhere outside Korea or China (total). We see that approximately 3 out of 8 foreign born living in the US have an international collaboration with someone in their home country and that this is slightly lower than the pattern exhibited by the foreign born working or studying in any of the 16 core countries. We also see that Koreans living in the US engage in collaborations with individuals in

their home country with marginally lower propensity than do the foreign born in general but foreign-born Koreans residing in any core country (total) are substantially less likely to engage in such collaborations than are the foreign born in general. There is very little difference in patterns of national collaboration between the Chinese and Koreans residing in the US. Chinese residing outside the US, however, are more likely to collaborate with individuals from their home country than are the handful of Korean respondents residing outside the US.

Table 6 - Percentage of foreign born researchers who collaborate with one or more individuals in the home country

Current Country	From any other origin country	From Korea	From China
USA	38.17	35.9	33.76
Total	42.25	34.1	38.04

Table 7 examines what can be thought of as the "diaspora" effect, that is the propensity of the foreign born to collaborate with nationals who have migrated to a third country. For those residing in the US, we find no evidence that the diaspora effect differs between Koreans and other foreign born. Once we extend the analysis to the foreign born residing in any core country, however, we find the diaspora effect to be slightly less prevalent among Koreans. This may reflect the tendency of Koreans to go abroad for training but return home for employment (Kim, 2010). Regardless of current location, the diaspora effect is found to be larger for Chinese than for Koreans. This may reflect a lower propensity to return to the home country on the part of Chinese emigrants as well as the "power" of numbers: Compared to Koreans, a relatively large number of Chinese work and study outside of China and the US.

Table 7 - Percentage of foreign-born researchers who collaborate with nationals who have migrated to different Core Country

Current Country	From any other origin country	From Korea	From China
USA	16.36	15.38	20.25
Total	19.08	16.0	21.47

V. Econometric Analysis

In prior work we examine the presence of a correlation at the individual level between international mobility and the scope of the international research network by estimating a set of econometric models (Scellato, Franzoni, & Stephan, forthcoming). In order to provide context for the results that distinguish Koreans from other foreign born, we first present these results. In these estimations we control for researchers background, scientific fields and country of residence. In particular, we analyze the correlation between mobility status and the scope of the respondent's international research network, measured by whether the respondent reported collaborating with individuals living outside the current

country of work or study in the past two years. For this purpose, we have created the discrete ordered variable NETWORK SIZE which takes the value of 1 for those with no international collaborations in the past two years, two for those with collaborations in just one other country, three for those with collaborations in two to four countries and four for those with collaborations in two or more countries. These levels of the ordered discrete dependent variable correspond to the thresholds used in Table 4. The measures of international scope of the research network are self-reported by respondents of the survey.

Our models include a set of author-specific characteristics. In particular we control for: age (AGE), a dummy variable for gender (FEMALE), a dummy variable for whether the respondent has a job position that allows full research independence, i.e. professorship (INDEPENDENT), a self-reported indicator on a 1-5 scale of the average importance of research collaboration in the specific scientific sub-field of the respondent (IMPORTANCE OF COLLAB).

We also include in all model specifications a set of four dummies for the broad scientific field of the respondent (Biology, Chemistry, Earth Science, Material Science), a set of three institution dummies (University, Public Research Institution, other nonprofit institutions) and a set of 16 country dummies (related to the country of residence of the respondent when the survey was filled in). With regard to the mobility status of the respondent, we have defined three dummy variables FOREIGN BORN, RETURNED, and NONMOBILE. The latter is the omitted variable in all model specifications. The dummy variable RETURNED equals one for those researchers who declared having spent time abroad for PhD study, a postdoc position or a job and had returned to the origin country at the time the questionnaire was filled out.

Table 8 summary statistics of variables used in the econometric analyses

Variable	Mean	Median	St dev	1st cent	99th cent
NETWORK SIZE	2.616	3	0.994	1	4
INTERN CO-AUTHORED	0.259	0	0.438	0	1
FOREIGN BORN	0.231	0	0.421	0	1
RETURNED	0.299	0	0.458	0	1
AGE	48.100	47	10.87	29	75
FEMALE	0.239	0	0.426	0	1
INDEPENDENT	0.622	1	0.484	0	1
IMPORTANCE OF COLLAB	3.483	3.5	1.001	1	5
SIZE	4.932	4	2.893	1	5
CORE PROJ	4.195	4.5	0.909	1.4	5

Table 9 presents results of an ordered probit model testing for the presence of significant correlations at the individual level between mobility status and the size of the international network of scientific collaboration of respondents. In model I we show the baseline specification while in models II and III we test for the additional impact exerted by the mobility status of the respondent. In these latter model specifications the omitted mobility status dummy is the nonmobile researchers. Hence, the variables FOREIGN BORN and RETURNED estimate differentials in the scope of the international networks of these

classes of researchers with respect to local nonmobile natives, net of country and field effects and other individual level controls. As expected, in all model specifications both age and the variable capturing job independence have a positive and significant effect on the scope of the international research network. Of more importance to this research is that the foreign-born variable shows a significant effect (Model II) and a higher impact than the returned effect in model III. The computation of marginal effects for specific outcomes of the rank ordered dependent variable NETWORK SIZE reveals that foreign born have, ceteris paribus, a 7.12 percent higher likelihood of having a large research network (more than four countries) than natives nonmobile. The same marginal effect is 5.5 percent for returnees and the larger network scope of foreign born vs. returnees is statistically significant at 99 percent level.

In Model IV we adopt an instrumental variables approach. This is motivated by the fact that the unobservable ability of individuals can be correlated both to migration and scientific performance. Individuals of higher quality might more likely be approached by colleagues for establishing collaborations at international level and may also be more likely to migrate. In order to address this problem of endogeneity, we choose to instrument the variable FOREIGN BORN with migration events that occurred during childhood (Franzoni, Scellato, & Stephan, 2014). We expect mobility during childhood to be correlated to migration decisions in adult life because prior experience of relocation makes one more open to relocation opportunities, more able to overcome cultural shocks, et cetera associated with mobility. At the same time, migration during childhood is arguably not affected by individual performance, because relocation events occurring before the age of 18 likely reflect parental decisions, rather than choices of the respondent. [7] Results for Model IV confirm the presence of a significant collaboration premium of foreign born, even after accounting for individual characteristics related to mobility, although with a larger confidence interval.

[7] Scientists who migrated during childhood are coded from the whole dataset as those reporting a country of birth different from the country of residence at age 18. Correlation of the dummy variable Child Migration with *FOREIGN BORN*=0.19***. Summary statistics of the dummy variable Child Migration: Mean=0.05; St.dev.=0.22. The ordered probit model with instrumental variables has been estimated with the CMP routine of STATA 12 which implements a recursive mixed process estimator developed by Roodman (2011).

Table 9 - Ordered probit model on international network size (Baseline models I-III). Instrumental variable ordered probit model (model IV). Dependent variable NETWORK SIZE.

MODELS	I	II	III	IV
FOREIGN BORN		0.204***	0.278***	0.263*
		(0.023)	(0.024)	(0.142)
RETURNED			0.223***	0.223***
			(0.022)	(0.022)
AGE	0.007***	0.007***	0.007***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)
INDEPENDENT	0.308***	0.321***	0.302***	0.302***
	(0.025)	(0.025)	(0.025)	(0.025)
FEMALE	-0.225***	-0.223***	-0.214***	-0.214***
	(0.022)	(0.022)	(0.022)	(0.022)
IMPORTANCE OF COLLAB	0.181***	0.180***	0.183***	0.183***
	(0.009)	(0.009)	(0.009)	(0.009)
Institution dummy	Yes	Yes	Yes	Yes
Current Country dummies	Yes	Yes	Yes	Yes
Field dummies	Yes	Yes	Yes	Yes
Constant cut1	0.492***	0.613***	0.612***	0.608***
	(0.073)	(0.074)	(0.074)	(0.081)
Constant cut2	1.120***	1.243***	1.246***	1.242***
	(0.073)	(0.074)	(0.074)	(0.081)
Constant cut3	2.492***	2.618***	2.626***	2.622***
	(0.074)	(0.076)	(0.076)	(0.083)
Observations	15,109	15,109	15,109	15,109
Pseudo R-sq	0.0772	0.0791	0.0817	-
Log Lik	-18148.4	-18109.8	-18058.9	-26421.5
Chi-Sq	3035.1	3112.3	3214.2	3184.5

*Standard errors in parentheses. Significant at *,**,***: 90% ,95%, 99%. Model IV: instrumental variable ordered probit model. Foreign Born instrumented with the variable Child Migration.*

Table 10 restricts the analysis to collaboration patterns of scientists studying or working in the United States and further distinguishes between Korean migrants and non-Korean foreign born. The results are striking, indicating that the international networks of Koreans working or studying in the United States are no different than the underlying benchmark of US natives who have never experienced mobility and their participation rate in international networks is significantly lower than the foreign born who are not Korean.

Table 10—Ordered Probit model on international network size for scientists residing in the US

FOREIGN_NO_KOREAN	0.2465***
	(0.038)
FOREIGN_KOR	-0.2651
	(0.189)
RETURNED	0.1991***
	(0.062)
AGE	0.0139***
	(0.002)
INDEP_LEADER	0.1293**
	(0.053)
FEMALE	-0.1705***
	(0.043)
UNIVERSITY	-0.1185
	(0.096)
PRO	0.0834
	(0.160)
COLL_PROP	0.1534***
	(0.017)
FIELD1	0.0873
	(0.060)
FIELD2	-0.1173*
	(0.062)
FIELD3	0.2797***
	(0.064)
Constant	0.6462***
	(0.147)
Constant	1.2824***
	(0.148)
Constant	2.6090***
	(0.151)
Observations	3,938

Pseudo R-sq	0.0286
Log Lik	-4943.4627
Chi-Sq	291.1937
DF	12.0000

In an effort to gain some insight into the differential patterns, we re-estimate equation II of table 9, differentiating the foreign born by four entry points: entry for the BA/MA degree; entry for the PhD; entry for the postdoc position and entry for work. The idea behind this division of foreign born is that foreign born who have been trained in the destination country should have limited "international" social capital (e.g. no previous research networks abroad established during their training and research career) compared to the foreign born who trained outside the country before entering or worked outside the country before entering. As expected, we find evidence of a moderating effect of training in the destination country on the outperformance of foreign born in terms of international networking. The results suggest that the aggregated "foreigner premium" effect is driven mostly by mobile researchers with previous training or work experience outside of the destination country, i.e. by individuals who had likely formed a rich knowledge network prior to entering the destination country. Immigrants for a postdoc represent a clear example of this typology of researchers. Our findings are consistent with the idea that at the time of migration senior scientists have more social capital with established scholars than do scientists who migrate early in the training process.

Table 11 - Ordered Probit model on international network size. Foreign split into subgroups

ENTRY BA_MA	0.174***
	(0.047)
ENTRY PHD	0.159***
	(0.040)
ENTRY POSTDOC	0.349***
	(0.033)
ENTRY JOB	0.460***
	(0.057)
RETURNED	0.227***
	(0.022)
AGE	0.006***
	(0.001)
INDEPENDENT	0.297***
	(0.025)
FEMALE	-0.213***
	(0.022)
IMPORTANCE OF COLLAB	0.183***

	(0.009)
Institution dummy	Yes
Current country dummies	Yes
Field dummies	Yes
Constant cut1	0.587***
	(0.074)
Constant cut2	1.222***
	(0.074)
Constant cut3	2.604***
	(0.076)
Observations	15,109
Pseudo R-sq	0.083
Log Lik	-18042.3
Chi-Sq	3247.4

*Standard errors in parentheses. Significant at *,**,***: 90% ,95%, 99%.*

These results also provide insight as to why Koreans working outside of country may have fewer international collaborations than do the foreign-born in general. The answer may rest on the fact that Koreans residing outside of country are more likely to have come for study than are other foreign nationals. This is examined in table 10 which compares the entry point of Koreans to the entry point of other foreign nationals who are in the USA. We see that a third of all Koreans in the GlobSci survey residing in the US came for a BA degree, compared to one-fifth for those from other countries; almost 60 percent came for a PhD., compared to 25.76 percent for those from other countries. To the extent that social capital is formed through education and that individuals collaborate with those whom they have studied with or met while training, this puts Koreans at a distinct disadvantage in forming international collaborations. China is somewhat similar. However, the difference with Korea is that a larger percent come for postdoctoral study and 10 percent come for a job.

Table 12 - Entry points of foreign born in the USA

Entry point	From Korea	From China	From any other country
BA	32.56	22.96	20.24
PhD	58.14	51.85	25.76
PostDoc	9.30	22.22	43.05
Employment	0.0	2.96	10.65

The reasons Koreans come for study also differ somewhat from those of other foreign born in the United States. This can be seen in table 13 which shows the mean responses to the importance immigrant respondents in the GlobSci survey ascribe to their reasons for coming to study in the United States. Again we differentiate between Koreans, Chinese, and all other foreign born. Note that a score of "1" means that the respondent rated the reason as being "totally unimportant," a score of "3" as being "neither important nor unimportant," and a score of "5"as being "extremely important."[8]

Most notable, perhaps, is the significantly higher ranking Koreans place on "the opportunity to improve my future career prospects in the country where I lived when I was 18." This response reflects the reality that for many years it was not uncommon for Koreans who aspired to a faculty position in Korea to first come to the US for training (Kim, 2010). This, of course, provided incentives for Koreans to stay in touch with individuals in Korea; it also suggests that the Koreans they met while studying abroad had similar aspirations and were unlikely to move to a third country, limiting the opportunities for collaborations with a Korean diaspora working outside Korea.

Table 13 - Reasons for studying in the United States

How important was each of the following factors in your decision to study in the USA	NON KOREAN FOREIGN BORN	KOREAN FOREIGN BORN	T-test vs non Korean foreign born	CHINESE FOREIGN BORN	T-test vs non-Chinese foreign born
prestige/ research excellence of the institution	4.29	4.66	**	4.61	***
fellowship that I obtained from the host country / institution	3.72	4.01	*	4.22	***
fellowship that I obtained from the country where I lived when I was 18	2.00	2.38	*	2.14	
availability of an exchange or joint programs between institutions	1.85	2.27	**	2.18	***
opportunity to improve my future career prospects	4.48	4.71	*	4.67	***
opportunity to improve my future	3.27	4.03	***	3.77	***

[8] Although responses may suffer from recall bias, there is little reason to believe that biases are country specific, either in terms of country of origin or country of destination. On the other hand, responses undoubtedly relate to preferences and circumstances of the respondents and these may vary across country of origin and/or country of destination.

career prospects in the country where I lived when I was 18					
contact with somebody (a professor, colleague, friend..) in the host country	3.12	3.20		3.04	
few if any good PhD programs in the country where I lived when I was 18	2.98	2.59	*	3.22	***
appeal of the life style or international experience	3.64	3.57		3.69	
family or personal reasons	2.43	2.81		2.54	

VI. Conclusion

Here we use data from the GlobSci survey to study the extent to which international collaboration relates to the mobility of researchers. Our data allow us to study the foreign born working or studying in one of 16 core countries. For the core countries, we can also look at collaboration patterns of nonmigrants and returnees. Because Korea was not a core country, we are only able to use the data to study collaboration patterns of Koreans living outside of Korea. The sample size is not that large, so care must be taken in interpreting our results. We have similar restrictions on our ability to study collaboration patterns of Chinese, although in this case the sample size is much larger.

Our research suggests that international collaboration is closely linked to the mobility of researchers. The group at the greatest disadvantage with regard to international networks is the nonmobile: the foreign born have larger networks as do returnees. Moreover, when it comes to the foreign born, the extent of their international networks is related to when they entered the country: those who enter for training at either the bachelor's, master's, or PhD level have smaller networks than those who entered for postdoctoral training or for work.

Our research suggests that the breadth of the international networks of Koreans working in the United States is considerably smaller than that of other foreign born working in the United States. Holding other things equal, we find no difference between the size of the international network of Koreans vs. the network size of individuals working in the US who have never experienced mobility. It is significantly lower than that of other foreign-born working or studying in the United States. One likely reason is the fact that the vast majority of Koreans who were working or studying in the United States at the time they replied to the GlobSci survey had come for training at the PhD or pre-PhD level. Few came for postdoctoral study or for work, suggesting that they had less social capital to bring with them at the time they emigrated. Another factor is that Koreans often go abroad with the specific goal of augmenting their skills and returning to Korea. As a result, the Korean diaspora of researchers is less dense than that of many countries. To the extent international networks add value to the sending country, the finding suggests that Korea might benefit by sending scientists abroad for either postdoctoral training or for work. It could also benefit by creating programs that enhance collaboration

between emigrant scientists and scientists located in Korea, such as short term visiting faculty positions. This may be of increasing relevancy given that the stay rate for Korean-US-PhD recipients has almost doubled in recent years.

Our findings, however, are nuanced. Yes, Koreans working or studying in the United States are less likely to have international collaborators, or, if they do, to only collaborate with individuals in one country. But, if they collaborate, those collaborations are likely to be with Koreans, as is evidenced by the fact that a higher percent of the Koreans have a coauthor in their country of origin on the focal paper than do other respondents in our sample and Koreans are almost as likely to report having collaborated with someone in their home country as are other foreign born. We conclude that, to the extent knowledge flows from the collaborations of Korean migrants, it flows back and forth between the US and Korea.

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