

Do Return Requirements Increase International Knowledge Diffusion?

Evidence from the Fulbright Program

Shulamit Kahn*

Megan MacGarvie**

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Abstract: A large percentage of the doctoral recipients in science and engineering at U.S. universities are international students, and most of these students are still in the U.S. ten years after the completion of their degrees. This has led to concern in sending countries about “brain drain” and to policies designed to encourage return migration. We ask whether such policies increase knowledge diffusion to home countries, as measured by citations to published articles in science and engineering journals. We track the post-Ph.D. careers of 249 recipients of the Fulbright Foreign Student Fellowship (who are required to leave the U.S. after the completion of their doctoral studies), and 249 similar foreign-born “control” scientists (who are not subject to return requirements). We find that scientific articles by Fulbright Fellows subject to return requirements are cited more per article in their home countries than articles by controls, and that this “Fulbright premium” is largest and most robust for researchers from low-income countries or countries with weak science bases. This is explained partly by the fact that return requirements have a larger effect on the propensity to return home for scientists from low-income countries, and partly by the fact that location in the home country has a bigger impact on citations from low-income countries. In addition, Fulbrights from countries with weaker science capabilities redirect their own citations away from U.S. articles and towards articles by authors in the home country. Overall, the results highlight the asymmetric effects of return requirements on knowledge diffusion for high- and low-income countries.

* Boston University, ** Boston University and NBER. 595 Commonwealth Ave., Boston, MA, 02115. Email: mmacgarv@bu.edu. We are grateful to Chelsea Carter, Megan Doiron, TJ Hanes, Giulia La Mattina, Chris Salviati, and especially Olesya Baker for excellent research assistance. We thank Scott Stern, Kira Fabrizio, Paula Stephan, and participants at seminars at UC Merced, the NBER High-Skill Immigration Meetings, and the University of Melbourne IPRIA Conference for comments and suggestions. This project is funded by National Science Foundation Grant SBE-0738371.

International students make up a large percentage of the doctorates granted in Science, Technology, Engineering and Mathematics (STEM) at US universities. This percentage has steadily increased in recent decades, rising by 49% between 1983 and 2009 (NSF Science and Engineering Indicators 2006, 2012). Most international students remain in the U.S. ten years after the completion of their degrees (Bound, Turner and Walsh 2009, Finn 2010). However, stay rates may be showing signs of change: the share of international students receiving doctorates in science and engineering who remain in the US increased from 45% to 67% between 1989 and 2005, but declined to 62% in 2009. (NSF Science and Engineering Indicators 2012, p. 3-6).

A number of policies exist to encourage return migration. Many students at US doctoral institutions who are funded by foreign governments receive J-1 visas; these visas require students to leave the US after the completion of their studies. Over the past 10-20 years the Chinese Ministry of Education and National Research Council (NSFC) has encouraged expatriate scientists to return to China through a variety of programs that supplement salary and/or offer research funding (Jonkers 2008, p. 16). In Argentina, the Ministry of Science and Technology has established a program called RAICES (Red de Argentinos Investigadores Cientificos en el Exterior) that manages a repatriation fund which helps cover moving costs for those who return home permanently (Jonkers 2008, p. 18). Related programs exist and are increasingly being adopted in other countries.

Despite the investments in these programs, there currently exists little evidence on their effects. Jonkers (2008) questions the extent of the contribution to domestic science made by the scientists lured to China through repatriation programs (p. 16). Other scholars have argued that highly-skilled expatriates may contribute to economic growth in their home countries despite

living abroad. Saxenian (2002a) argues that “Most people instinctively assume that the movement of skill and talent must benefit one country at the expense of another. But thanks to brain circulation, high-skilled immigration increasingly benefits both sides.”¹

In prior research (Kahn and MacGarvie 2013), we have shown that requiring doctoral recipients to return to countries with low GDP per capita is associated with a reduction in research productivity for returning scientists, suggesting that there is a substantial opportunity cost in terms of research productivity associated with return requirements.² This foregone research output may be less troublesome if the research conducted by returning researchers contributes more than it otherwise would to the development of science in the home country, for example, if the ideas created by returning scientists diffuse more readily to the home country than they would if the scientist had remained abroad. In this paper, we ask whether return requirements increase the diffusion of knowledge. We base our analysis on a sample of participants in the Foreign Fulbright Program, who come to the US on the aforementioned J-1 visas.³ We match these Fulbright Fellows to a sample of control scientists who are apparently not subject to return requirements but are otherwise similar. We then examine how return requirements affect the rate at which articles by the scientists in our sample are cited in the home country. We also examine the relationship between return requirements and the citations made by our scientists, as well as citations to and from US-based researchers.

We find that on average, scientific articles by Fulbright Fellows (subject to return

¹ In a survey of immigrant professionals in Silicon Valley, Saxenian showed that around half of these entrepreneurs have business activity in their home countries, and over 80% share information about technology with acquaintances in their home countries (Saxenian 2002b, p. 27). Examples of this are apparent in the contributions made by Silicon Valley-based Indian expatriates to the development of India’s IT industry, as well as return migration by South Korean and Taiwanese scientists and engineers trained in the United States (Ashok Parthasarathi, “Turning brain drain into brain circulation”, Science and Development Network, <http://www.scidev.net/content/opinions/eng/turning-brain-drain-into-brain-circulation.cfm>, accessed June 12, 2006).

² There is no disparity in productivity between Fulbrights and controls from high-income countries.

³ Specific details of this requirement are discussed below.

requirements) are cited no more frequently in their home countries than articles by controls. However, on a per-article basis, they are cited 113% more. Further, we find that the impact varies with home-country income per capita. There is a “Fulbright premium” in which Fulbrights from low-income countries are cited more than three times as much per article at home as controls from similar countries. This premium is not explained by a higher tendency among Fulbrights to publish in regional journals or in the scientific fields in which the home country has the greatest strength. Instead, the Fulbright premium appears to be primarily explained by the fact that Fulbrights are much more likely to be located in their home countries than are controls without return requirements. Thus a scientist who returns to a low-income country publishes fewer papers, but each paper is better known at home, and the latter effect dominates. In contrast, neither effect (fewer papers and more home citations) is observed consistently for those returning to high-income countries.

This suggests that low-income per capita home countries gain scientific knowledge when US-trained expatriate scientists are required to return home. Is there a corresponding loss of this scientific knowledge to the US? To investigate this, we study (forward) citations to articles by Fulbrights and controls from US-based science. We find no average difference in citations by US scientists to scientists with return requirements, and no reduction in US citations for Fulbrights from high-income countries. Isolating poorer countries, we find that Fulbrights are cited less per article than controls from these countries. However, this effect is not robust when we measure the science base of the home country more directly (rather than using income as a proxy for the science base); nor is it robust to specifications that control for journals’ regional orientation and detailed field. There is thus little conclusive evidence that poorer home countries’ gain from returning scientists comes at the cost of less scientific knowledge in the US.

This study also examines backward citations by Fulbrights and controls to articles by US authors, which allows us to ascertain whether the returning scientist continues to incorporate knowledge from the US into their work, particularly as time passes. We find that, on average, Fulbrights' backwards citations to the US are maintained for about nine years post-PhD, although there is some limited indication that it may fall beyond this point. The decline in backwards citations to the US is more significantly negative for Fulbrights from countries with weaker science bases as opposed to low-income countries. Meanwhile, backward citations to the home country by Fulbrights increase over time relative to controls. This suggests that, over time, Fulbrights' research agendas are redirected towards topics that are of greater relevance in the home country and of less relevance in the US.

Literature Review

Prior research has documented the large share of foreign students in U.S. graduate programs (Bound, Turner and Walsh 2009) and their strong tendency to remain in the U.S. Finn (2010) finds that 62% of foreign-born scientists & engineers who obtained Ph.D.'s in the U.S. in 2002 were still in the U.S. in 2007. The five-year stay rate for students from China (the most common country of origin for foreign students in the U.S.) is 92%, and for Indians (the second most common country) the stay rate is 81%. Gaule (2011), in a survey of academic chemists, finds that only 9% of foreign-born faculty in the U.S. return to their home country during their professional career.

A second body of research documents the positive externalities to scientific diffusion as a consequence of geographic proximity. For instance, Jaffe and Trajtenberg (1999) documented "home country bias" in knowledge diffusion as measured by patent citations, while Zucker and

Darby (2006) find that the presence of star scientists in a region increases the rate of high-tech firm entry in related fields. These findings combine to suggest that policy makers in foreign countries may have reason to be concerned about the migration of some of its most highly-skilled citizens to the U.S. or other high-income countries.

Another set of papers, however, points to the diffusion of knowledge through long-lasting social ties that do not require geographic propinquity. In a survey of immigrant professionals in Silicon Valley, Saxenian (2002b) showed that around half of these entrepreneurs have business activity in their home countries, and over 80% share information about technology with acquaintances in their home countries. Kerr (2008) finds that co-ethnicity appears to spur knowledge flows between inventors, with non-U.S. inventors citing U.S. inventors of the same ethnicity 50% more often. Kerr uses exogenous variation in migration patterns associated with changes in U.S. migration quotas to identify the effect of international migration on knowledge diffusion. Agrawal, Cockburn, and McHale (2006) develop a model of investment in social relationships, which generates the prediction that, when an inventor moves to a new location, knowledge will flow disproportionately back to the inventor's *prior* location. They find empirical evidence that, indeed, mobile inventors are disproportionately more likely to be cited by patents invented in the prior location. Nonetheless, Agrawal, Kapur, and McHale (2008) find that patent citation rates between inventors located in India are 6 times higher than between non-co-located Indian inventors, suggesting that the net effect on knowledge flows from emigrating inventors is negative.

Of course, the two facts are not mutually exclusive. Geographic proximity and persistent social ties despite geographic distance might both promote knowledge diffusion. Azoulay, Graff, Zivin, and Sampat (2011) have found just that. They show that academic citations to papers by

scientists who move to a new location increase dramatically in the new location and do not change in the old location. Using information from the dismissal of Jewish scientists from Nazi Germany, Waldinger (2012) finds no evidence for peer effects: the productivity German scientists was unaffected by the expulsion of Jewish colleagues. However, Waldinger estimates substantial long-run negative effects on scientific research in German universities affected by the dismissal of Jewish scientists in World War II relative to universities less affected by dismissals. Moser, Voena and Waldinger (2013) show that the emigration of Jewish scientists from Germany to the US during the war led to a substantial increase in chemistry inventions in the US.

Informed by this prior work, this paper hypothesizes that foreigners who receive US doctorates and then return to their home countries may transfer the information they acquired during their studies about scientific and technological knowledge created at U.S. universities. Further, we believe that the relationships that develop in the course of doctoral study are likely to persist when doctoral recipients move to a different location. These individuals may remain in contact with dissertation advisors and fellow students, possibly collaborating with them on research projects and thereby sharing knowledge, possibly in both directions. This paper will investigate the extent to which both geographic proximity and persistent social relationships help to diffuse scientific and technological knowledge between U.S. universities and foreign inventors.

Data

The Fulbright Foreign Student Program,⁴ established in 1946 and primarily sponsored by the US Department of State, is the main US government program that brings students from other countries to pursue graduate study in the United States. The program has to date given

⁴ Also called the Fulbright Visiting Students Program.

scholarships to more than 125,000 foreign students to do graduate work in the US. According to the Department of State, the Fulbright program is “our country’s premier vehicle for intellectual engagement with the rest of the world.” Students who receive a Fulbright Scholarship for study in the US are awarded a J-1 student visa. A recipient of the J-1 visa must demonstrate that he or she has spent at least two years in his home country after the completion of his studies before applying for a visa such as the H1-B or permanent resident status that would allow him to remain indefinitely in the US.

We have collected a sample of 249 Fulbright scholars who were receiving a Fulbright foreign student fellowship to study in an American doctoral program in a science or engineering field between 1993 & 1996 and who received a PhD in the U.S. between 1993 & 2005.⁵ To create this sample, we took all Fulbright scholars who completed a PhD at the institution listed in the *Foreign Fulbright Fellows: Directory of Students* published in 1993-96 for whom we could identify a location for whom we could identify a control. These controls are non-Fulbright foreign students who are as similar as possible to the Fulbright in terms of research potential. The characteristics that we *a priori* believed to be most relevant for research potential while being easily identifiable included institution, advisor/field, date of graduation and, where possible, region of origin. Therefore, we used the *Proquest Dissertations and Theses* database to obtain information on the year of graduation and advisor and to identify a “control” student of foreign origin who did *not* have post- PhD location restrictions, whose location could also be found on the web for at least half of their post-PhD years, and who was similar along the above dimensions, i.e. he/she graduated from the *same* program in the *same* year and, whenever such a

⁵ Our original sample as described in Kahn and MacGarvie (2011) consisted of 244 Fulbright-control pairs. We updated the location data after additional searches in June-July 2013, and were able to add 5 pairs that had previously been excluded due to lack of data.

student existed, with the same advisor and from the same region.⁶ Since students who receive substantial funding from their home country's government often are required to return for some period, we searched PhD acknowledgements for evidence of foreign governmental funding and did not include the student as a control if we found any.

When several potential control students were identified for a single Fulbright fellow, we chose the student who came from the same or similar countries as those represented in the Fulbright sample. There are no Fulbrights in our sample from China or India so we tried to avoid sampling controls from these countries, but when a suitable control could not be found from another country we allowed students of Chinese and Indian origin in the sample. Also, in our sample there are many Fulbrights from Mexico but few controls since most of the Mexican students in the US without Fulbright fellowships are subsidized by their governments. Kahn and MacGarvie (2013) provides a detailed description of the construction of the match between Fulbrights and controls.

Measuring Knowledge Diffusion, Retention and Acquisition

Our key measures of knowledge diffusion, retention and acquisition are based on the number of forward citations made by authors in different countries to articles published by the scientists in our sample (which we will refer to here as “source articles”) and the number of backward citations made by these source articles to authors in different countries. Both forward and backward citation data were provided by Thomson-Reuters.

Citations to published articles clearly do not capture all knowledge diffusion. Scientists may contribute to knowledge in their home country in many ways that do not result in a

⁶ In cases where there was no control student with the same advisor in the same year, we identified a student with the same advisor graduating within 3 years before or after the Fulbright. If no students met the latter criteria, we chose a student graduating in the same year in the same major field, but with a different advisor.

published article, for example by teaching and advising students, participating in conferences, consulting with industry, and so on. Our focus here is limited to knowledge diffused to scientists who then build upon that knowledge in their own published work.

We identify the location of the citing publication using the reprint address, or the address of the author one should contact when requesting a reprint of the article. Most citing articles have multiple authors, potentially located in different countries. Some collaborators on many-author scientific articles may make relatively small contributions to the research. We use the reprint author to determine the location of the citing article because we assume that this author is more likely to be closely connected to the research than a randomly chosen author. This assumption is based on our experience reading the bibliographic information of publications on Web of Science, in which the reprint author commonly was the first or last author.

We focus on the following main dependent variables:

Forward citations:

1. *Number of (forward) citations in articles published in year T by authors in the scientist's country of origin, to articles published by the scientist in year t*
2. *Number of (forward) citations in articles published in year T by authors in the USA, to articles published by the scientist in year t*

We analyze forward citations to articles authored by the scientist beginning in the year after completion of the Ph.D. , up to 2007.

Backward citations:

3. *Number of backward citations in articles published in year T by the scientist to articles published in year t by authors in the scientist's country of origin*
4. *Number of backward citations in articles published in year T by the scientist to articles*

published in year t by authors in the USA

These variables count all backward citations captured by Thomson-Reuters in source articles published from the year after the researcher's Ph.D. graduation up to and including 2007.⁷

In an attempt to exclude journals with a purely regional or national focus in our results on knowledge diffusion, we also computed:

5. *Number of (forward) citations (from location k) to articles published in global journals:*

We defined "global journals" as journals without a country or region name in the title.

We also excluded journals published in non-English languages. Examples of excluded journals include *Australian Journal of Agricultural Research*, *Tierärztliche Praxis Ausgabe Grosstiere Nutztiere*, *Revista Mexicana de Astronomia y Astrofisica*.

As described above, social ties may enhance knowledge diffusion. It is possible that citations to and from the US are driven by papers coauthored with scientists' dissertation advisors. This would cause us to over-estimate the amount of knowledge diffusion that occurs between scientists and the US, since the dissertation advisor may be the one acquiring and disseminating the information reflected in the citations. In order to investigate this possibility, we also compute:

6. *Number of forward and backward citations excluding articles co-authored with the student's main advisor:* we compute backward and forward citations after dropping source articles with an author list that contains the surname of the primary dissertation advisor.⁸

These measures will capture knowledge diffusion via citations only imperfectly, for several reasons. First, there may be some work published in relatively obscure journals in the

⁷ Our collection of article data began in 2008, which is why the sample is truncated in 2007.

⁸ This variable is not available for 39 scientists whose dissertation advisor was not listed on Proquest.

home country which are not indexed in Web of Science. However, we performed an investigation of scientists' CVs in which we calculated the percentage of the number of articles listed on a scientist's CV that are indexed on Web of Science, and compared this percentage for US-based scientists and those based abroad. We found no significant difference in this measure between US and foreign scientists.

Secondly, if certain countries have agglomerations of researchers in certain fields, we may be more likely to observe citations between a scientist from that country and scientists at home. This could reflect the similarity of their research agendas rather than an increase in the rate of knowledge diffusion due to location. Moreover, the Fulbright commissions in each country may be biased towards selecting students who are most likely to be able to contribute to these fields upon their return. We will investigate this possibility in the results below.

Empirical Model

We estimate a regression model of citation frequencies that draws on the Jaffe-Trajtenberg (1999) model of patent citations and the Adams-Clemmons (2006) model of citations to scientific publications. These papers model a paper's citation frequency measured as the ratio of actual to potential citations, which in our application would be:

$$P_{itFT} \equiv C_{itFT} / (N_{it} * N_{FT})$$

where C_{itFT} is the number of citations to a paper published by author i in year t from papers in field-country F in year T . The denominator is the product of the number of potentially citing papers (N_{FT}) and potentially cited papers (N_{it}). This product is the maximum number of citations that *could* be made to articles published by author i in year t , so P_{itFT} measures the ratio of actual to potential citations. Combining actual and potential citations in this way assumes that potentially cited and potentially citing papers have the same proportional impact on citations and

that this ratio does not vary with the level of N_{it} or N_{FT} . To relax (and test) these assumptions, we model C_{itFT} as our dependent variable and include N_{it} and N_{FT} as explanatory variables.

Jaffe and Trajtenberg (1999) and Adams and Clemmons (2006) model this ratio as a function of time since publication with a functional form that allows them to estimate the rates of diffusion and obsolescence of the knowledge. We instead choose to use a more general semi-parametric functional form since we are not particularly interested in estimating the diffusion/obsolescence parameters and since our data is discrete (annual). Specifically, we include a separate dummy for each value of the lag $T-t$ (α_{T-t}). We also add controls Z_{itFT} and dummy variables for the year of citation T (α_T).

Because citations are a discrete non-negative variable bounded by zero (a count), we use econometric methods for count data to estimate the parameters of the above model. Branstetter (2000) also uses count data regressions derived from the Jaffe-Trajtenberg framework to estimate the relationship between FDI and patent citations at the firm level. The Poisson regression model treats the dependent variable as drawn from a Poisson distribution with intensity λ_{itFT} :

$$C_{itFT} | \lambda_{itFT} \sim \text{Poisson}(\lambda_{itFT}).$$

so that $E(C_{itFT} | \lambda_{itFT}) = \lambda_{itFT}$. We can express the conditional expectation of the dependent variable as:

$$E[C_{itFT} | N_{it}, N_{FT}, Z_{itFT}] = \exp(\beta_1 \ln(N_{it}) + \beta_2 \ln(N_{FT}) + \delta Z_{itFT} + \alpha_T + \alpha_{T-t})$$

Again, C_{itFT} is the number of forward citations made by publications in field-country F in year T to papers written by scientist i in year t ; N_{FT} is the number of papers published by authors in citing field-country F in citing year T ; and N_{it} is the number of papers published by cited author i in cited year t . We expect the β 's to each equal 1 if the original specification with p_{itFT} as dependent variable is correct. Cameron and Trivedi (1998) note that incorporating regressors

logarithmically in this way is “particularly appropriate if [the regressor] is a measure of exposure, such as the number of miles driven if modeling the number of automobile accidents...” (p. 81).

For the backward citation regressions, we collapse the citation data to the scientist-citing year level. This is because data on the number of articles published in the home country and field, which we use to normalize citations to the home country, only extends back to 1996 at the earliest. Therefore our dependent variable in the backward citation regressions is the sum of all citations made by the scientist to either the home country or the US in year t . As with the forward citation data, we drop self-citations and use the reprint address to identify the country of the cited article.⁹ Our controls for the number of potential citations are the log of number of articles published by the author in year t and the log of the number of articles published in the scientist’s field in his home country in year t (or the US in the case of citations to the US).¹⁰

Control variables

We control for N_{FT} , the number of potentially citing articles published in country F in the scientist’s field in citing year T . This variable comes from the Scimago Journal & Country Rank (2007).¹¹ The number of articles published by country and field are based on article data contained Elsevier’s Scopus database, and are computed by a research team from the Universities of Granada, Extremadura and Carlos III (Madrid).¹² To control for the number of

⁹ In a small number of cases in which the reprint address is missing, we use the address of the first author listed on the paper.

¹⁰ It would be preferable to control for the number of articles published in the home country in each potentially cited year, but data limitations make this infeasible. However, we feel that the number of articles published in year t is a reasonable proxy for the set of potentially cited articles.

¹¹ See Borja González-Pereira et. al. (2009) for more about this measure.

¹² Retrieved April 03, 2012, from <http://www.scimagojr.com>. The data start in 1996, and for the 0.38% of observations with citing years before 1996 in our sample, we fill in the missing values with the number of articles in the country-field in 1996. In the final data, the number of articles in the home country-field is equal to zero for 0.42% of observations, consisting of scientists from Ghana, Haiti, Lesotho, Malawi, Panama, Swaziland, and Uganda. We include a dummy equal to 1 for these observations.

potentially *cited* articles N_{it} , we include the natural logarithm of the number of articles produced by the scientist in cited year t and indexed on ISI's Web of Science.¹³

All of the analyses include the following control variables:

Ranking of Ph.D. institution: We include the (log of the) 1995 relative ranking of the U.S. Ph.D. institution (by field) from the National Research Council (Goldberger et al. 1995) as a control for the quality of Ph.D. training. Note that a lower rank signifies higher quality. Rank is the same for Fulbright and control. Including this variable only increases the explanatory power of equations with pooled Fulbrights and controls.

Field dummies: We categorized each student by the first field listed in their (Proquest) dissertation record. These fields are the broad fields used by the NSF in its publications. In some specifications, we include more detailed field dummies as a robustness check, as described below.

Dummies for year of Ph.D receipt: We include a series of dummies for ranges of the PhD year as follows: pre-1997, 97-98, 99-00, -02, and post-2002.

Gender: We obtained data on the gender of the scientist using information from web searches (e.g. photographs, the use of personal pronouns in web bios), using a web-based algorithm for identifying the probable genders of given names when no other information was available.¹⁴

In addition, different specifications may contain the following control variables:

GDP per capita of the home country below the 75th percentile: In some specifications, we include a dummy variable equal to 1 if the real GDP per capita of the student's home country is below the 75th percentile of world countries in the year of completion of the doctoral degree.

¹³ We include a dummy variable equal to 1 for observations in which N_{it} is equal to zero. Results are, however, highly similar when this variable is included in linear form. Results are also robust to dropping observations for which N_{it} equals zero. Standard errors are clustered by scientists to account for the possibility of correlation across the residuals of observations on the same scientist.

¹⁴ The gender-guessing program is found at: <http://www.gpeters.com/names/baby-names.php>.

Home country below the 75th percentile of articles per capita in field: In some specifications, we include a dummy variable equals 1 if the scientist is from a country whose number of articles published per capita that year in the scientist's field is greater than the median value for other countries.¹⁵

Home country below the 75th percentile of forward citations per article in field: In some specifications, we include a dummy variable equals 1 if the scientist is from a country whose number of citations per article published that year in the scientist's field is greater than the median value for other countries.

Tables 1 gives summary statistics.

Results on Forward Citations from the Home Country

Table 2 contains the results of Poisson regression in which the dependent variable is the number of citations in articles in year T *in the home country* to articles published in year t by scientist i . In addition to the variables listed in the table, dummies for field, year of Ph.D., citing year (T), and citation lag ($T-t$) are included.

Column 1 indicates that there is no significant average effect of Fulbright status when neither controls for the number of potentially citing articles (N_{FT}) nor for the number of articles produced by the scientist (N_{it}) are included. Columns 2 and 3 add these two variables. Controlling for the number of potentially citing articles published in that country in the scientist's field (column 2), and this variable as well as the number of the scientist's articles (column 3) renders the coefficient on Fulbright significant at the 5% level, with a coefficient that corresponds to an 113% increase in the number of home-country citations. We thus conclude that each article by a Fulbright is cited more by their home country, and further that, although Fulbrights on average publish fewer papers, on net diffusion from the scientist to others in the

¹⁵ Source of numbers of articles Scimago Journal & Country Rank (2007)

home country increases when a doctoral recipient faces a return requirement.

In the next three columns, we allow the Fulbright effect to differ for those from lower-income countries (which presumably have less developed scientific infrastructures), and for those from higher-income countries. To ensure that we are not picking up the effect of being from a poor home country, we also control for whether the scientist – whether Fulbright or control, originated in a poor country.

Column 4 excludes the control for the scientist's own articles, and the coefficient on high-income Fulbright is significant at the 10% level, partially reflecting the higher productivity of these scientists. Controlling for the scientist's articles in column 5 is associated with a coefficient on low-income Fulbright significant at the 1% level, corresponding to a percentage increase in citations of approximately 222% compared to controls from countries below the 75th percentile of GDP per capita. We thus conclude that the work of scientists subject to requirements to return to low-income countries is better known at home. In contrast, the coefficient for Fulbrights from high-income countries is now positive, but not significant.

Do we observe similar effects when we differentiate according to the country's strength in science, as opposed to GDP per capita? Column 6 breaks Fulbrights into two groups: above and below the 75th percentile when countries are ranked by the number of articles produced per capita in the scientist's field that year. Column 7 distinguishes between countries by whether they are above or below the median country when countries are ranked by the number of forward *citations* per article in the scientist's field that year. Both columns control for the scientist's publications that year (although results without these controls are qualitatively similar to column 4 with countries ranked by GDP.) In all cases we see that the scientific laggards – the countries producing fewer articles per capita or articles that are cited less than the median – are where

Fulbrights are more likely to be cited than controls, consistent with the positive effect for low-income Fulbrights in Column 5. The difference in the size of the effect for the two groups is also larger when we distinguish between high-science and low-science, though the difference in the coefficients is not statistically significant for these regressions nor for the regressions in columns 4 and 5.

The coefficients on the “exposure” variables – the number of publications by the scientist (when in the specification) and the number of publications in the field/home country in the citing year – are highly significant in all specifications. The number of publications by the scientist is close to one, consistent with the idea that home country citations increase proportionally with the number of publications by the scientist. The coefficient on the number of publications in the field from the home country (i.e. publications with the corresponding author from the home country) is significantly less than one whenever the scientist’s publications are also controlled for. This may reflect the fact that fields we use are too broad so that our measure of potentially citing articles are larger than they should be. We will add more detailed controls for country-field articles in a later table.

Interestingly, scientists who are female are cited dramatically less often in their home countries, all else equal. The rank of the scientist’s PhD program (where a higher rank means a lower-status program) is negatively associated with home-country citations once scientist productivity is controlled for.

In regressions not shown, we re-estimated the basic model (column 3) controlling for the regular covariates but including Fulbright dummies for each year since PhD instead of a single Fulbright dummy. Figure 1 graphs the pattern of the coefficients on these dummies through 10

years post-PhD along with the 95% confidence bands.¹⁶ This graph indicates that as time since PhD increases, Fulbrights are cited more in their home country relative to controls. This reinforces the finding that being in the home country diffuses information to other scientists there: the fact that this diffusion increases over time suggests that it is the scientists' actual presence, rather than their topic of study, that increases the visibility of their publications in the home country.

Forward Citations from the USA

The above results suggested that poor and low-science home countries gain scientific knowledge when its US-educated PhD scientists are required to return home. Is there a corresponding loss of this scientific knowledge in the US? To investigate this question, Table 3 presents similar regressions in which the dependent variable is the number of citations in articles published in year T *in the USA* to articles published in year t by scientist i . The same specifications are included, with the exception that we no longer control for the number of articles in the home country, because for these regressions the number of potentially citing articles is the number of potentially citing articles by field in the US.¹⁷ Table 3 reveals that on average, there is no significant difference in US citations between Fulbrights and controls (Columns 1 -3). Citations from the US to scientists from richer or science-rich home countries are not different for Fulbrights and controls (Columns 4-7). However, there is a negative effect of -35.6% (coefficient -0.440) for low-income Fulbrights, significant at the 5% level, even after controlling for the number of articles produced by the scientist (Column 5). This suggests that the diffusion advantage gained by poorer home countries occurs at the cost of less scientific

¹⁶ Many scientists in our sample were not observed past 10 years post-PhD, making the coefficients beyond this point highly variable and with wide confidence intervals.

¹⁷ We control for this via the number of articles published in the US in the field in the citing year.

knowledge in the US. An alternative or perhaps complementary interpretation is that the knowledge produced by students who returned to their home countries is less relevant to scientists to the US than the knowledge produced by the students who did not return. Using our citations per article as a measure of the country's scientific strength, the coefficient was not statistically significant, however for Fulbrights from countries with low articles per capita, we do estimate a reduction in citations from the US significant at the 10% level.

Interestingly, after controlling for productivity, there is no significant reduction in citations from the US if the scientist is female, but the higher the status of the PhD program from which the scientist graduated (the lower the rank), the greater the number of citations made by US researchers.

As above, we re-estimated the basic model of column 3 adding Fulbright dummies for each year since PhD instead of a single Fulbright dummy. We graph these dummies in Figure 2. There appears to be a modest decline over time in citations from the US, but this is not statistically significant.

Explaining the Fulbright premium in forward citations

We have established that Fulbrights from low-income and low-science home countries have higher citation rates in their home country than controls. There are a number of potential reasons for this higher rate. The importance of geographic proximity for citations (Azoulay et al, 2011) combined with the return requirements associated with the Fulbright program may be the cause. One alternative is that the return requirement is only important in that it leads to Fulbrights and controls working in different sectors. For example, Fulbrights from low-income countries may be more likely to work in academia than controls from these countries who may

be able to obtain employment visas to work in industry in the U.S. In column 1 of Table 4, we introduce dummy variables that control for whether the scientist works in academia, industry or government to the specification from Table 2 column 5. The results are robust to adding these controls.

Another possibility is that we have not accurately captured the number of potentially citing papers using the country-level publication count. Perhaps Fulbrights are drawn from countries with particular strengths in their areas of research. To account for this possibility, in column 2 of Table 4 we include an additional field-specific measure of home countries' research strengths, measured by the home country's number of citations per publication in that field in the citing year.¹⁸ Including this control has little effect on the coefficient on the Fulbright X below 75th percentile interaction.

A different way to control for the possibility that Fulbrights' areas of research are more closely aligned with the research strengths of the home country is to exclude publications in journals with a regional orientation. In column 3 of Table 4, the dependent variable excludes citations to articles published in regional journals focused on the scientist's region of origin.¹⁹ We do not exclude from this count publications in regional journals in regions *other* than the scientist's home region. For example, a publication in a Canadian journal by a Japanese researcher would not be treated as a publication in a "regional" journal for the purposes of this exercise. We obtain similar results after dropping publications in journals focused on the scientist's region of origin. Column 4 excludes regional journals and also includes more detailed field dummies controlling for differences across 21 areas of scientific research, for example

¹⁸ These data were obtained from the Journal & Country Rank (2007). The country rankings are based on article data contained Elsevier's Scopus database, and are computed by a research team from the Universities of Granada, Extremadura and Carlos III (Madrid). Retrieved April 03, 2012, from <http://www.scimagojr.com>

¹⁹ We do not exclude citations *from* articles published in regional journals.

“oceanography” within the broad “earth/air/ocean” or “electrical engineering” within the broad “engineering/comp sci”. The coefficient on the Fulbright X Below 75th percentile interaction remains large and significant at the 1% level. Finally, because research in agricultural and environmental sciences may be more location-specific than other fields of science, and applicants may be more likely to receive Fulbright funding if they express plans to study these subjects, Column 5 completely excludes all scientists whose PhDs were in these fields. Here, the sample is reduced almost by half, and the coefficient on Fulbrights from low-income countries remains significant at the 1% level. Another possibility is that students are selected for Fulbright fellowships because they express interest at an early stage in research underway in the home country. If this explains our results, we would also expect this to be reflected in a larger number of citations made by the scientist to the home country in publications authored while the student is in graduate school. In column 6 we return to the full sample and control for the number of backward cites made by the scientists in their *pre-grad* publications to articles with a reprint address in the home country. This variable’s coefficient is not significantly different from zero, and including it only slightly reduces the coefficient on the low-income Fulbright dummy, which remains statistically significant at the 1% level.

Another potential reason for the aforementioned Fulbright premium in low-income home countries, besides the importance of geographic proximity, may be that the research of Fulbrights is simply of higher quality than that of controls. If so, this would also cause them to publish more articles in high impact journals, and to have more highly cited articles. Also, it would cause them to receive more citations not just from the home country, but also from all other countries. Column 7 of Table 4 shows that the estimated effect of being a low-income country Fulbright is robust to controlling for the share of articles published in high-impact journals.

In Column 8 of Table 4, we include as a control the log of the number of citations received in year T by the scientist's articles published in year t from *all* countries except the home country (including the US). This variable is highly significant. Nevertheless, Fulbrights from lower-income countries still receive many more home-country citations than controls from low-income countries, all else equal. The coefficient on low –income Fulbrights remains significant in column 10, where we drop the most highly cited 10% of articles.

Omitting any source articles that were co-authored with the scientist's main dissertation advisor as in Column 9, we observe that the low-income Fulbright citation premium remains the same, but surprisingly the coefficient for high-income Fulbrights becomes positive and significant at the 5% level. This implies that research pursued independently of one's advisor *is* cited more highly at home for those with return requirements. This may reflect the fact that dissertation advisors are well-known around the world, and collaboration with these prominent scientists dwarfs the effect of return requirements in the main specifications.

Table 5 repeats these regressions for citations originating in the US. We find that the negative effect of being a low-income Fulbright is robust (at the 10% level of significance) to including dummies for sector of employment and to excluding regional journals. However, excluding regional journals and controlling for narrow scientific fields, the effect is no longer significant. The same is true in Columns 4, which drops agricultural and environmental sciences, and 5, which controls for backwards citations to home-country articles in pre-graduation publications. However, the coefficient on low-income Fulbright is negative and significant in column 7, in which citations from non-US articles are included as a control. This latter finding suggests that the *share* of total citations coming from the US is lower for scientists required to return to low-income countries.

When we drop the most highly cited articles from the sample, in Column 9, we actually observe a negative coefficient on the high-income Fulbright variable. These results suggest that, while on average there is no significant reduction in the number of citations coming from the US for scientists from high-income countries subject to return requirements, this finding may largely be driven by the most highly cited papers in the sample. Papers with more moderate numbers of citations may indeed be less cited by the US when their authors are recipients of Fulbright fellowships.

Patterns in Backward Citations

Table 6 presents regressions of backward citations of the scientist's articles to articles published with a home-country corresponding author (other than him or herself). It indicates that on average, controlling for the number of publications in the home country and by the scientist, Fulbrights are more likely to cite articles from the home country (columns 2 and 3). Columns 4 through 9 indicate that this is particularly true for those Fulbrights from low-income or low-science countries, with Fulbright premia ranging from 167% to 326%. However, Fulbrights from rich or high-citation-per-article home countries are also more likely than controls to cite people from the home country. Excluding source articles that are collaborations with the main dissertation advisor does not affect the results appreciably. Figure 3 shows how this greater Fulbright tendency to cite home country work changes as the time since PhD receipt increases. As with forward cites, these backward cites rise over time, suggesting that Fulbrights increasingly become aware of and/or influenced by their home country colleagues, the longer they remain in the home country.

To round out our analysis, Table 7 models backward citations to the USA. On average,

we cannot reject the hypothesis that Fulbrights' and controls' articles cite US authors at the same rate (columns 1-3). Isolating low-income countries, the result remains insignificant. However, when we distinguish between scientists in science-rich and science-poor home countries (columns 5 and 6), we find that those in science-poor home countries cite US articles less frequently than controls (approximately 19% less). The coefficient on low-science Fulbrights becomes more negative after dropping articles co-authored with the scientist's principal dissertation advisor (columns 8 and 9, though the coefficient in column 9 is only significant at the 10% level). The decline in citations to the US appears to occur at some delay: The time-varying average Fulbright effect displayed in Figure 4 suggests that Fulbrights begin to cite US articles less starting at approximately 9 years post-PhD.

Citations and Location

Fulbrights may be different from controls in two ways. Firstly, and we expect this to dominate, Fulbrights are more likely to be in the home country because of their return requirements. Second, they may be different from controls in other ways, despite our attempts to match them other. How much more likely are Fulbrights to be located in the home country *ceteris paribus*? Table 8 presents the estimates of a linear probability model in which the dependent variable is equal to 1 if the scientist was located in his or her home country in year t (with same controls as in Table 2 Column 5). This table shows that *ceteris paribus*, Fulbrights from high-income countries are 27 percentage points more likely than high-income controls to be located in their home country and also 27 percentage points more likely to be located in other non-US countries. However, Fulbrights from low-income countries are a full 46 percentage points more likely than controls to be located in the home country, although only 19 percentage

points more likely to be located in other non-US countries.

In the first two columns of Table 9, we try to separate out the effects of location and Fulbright status from the forward citation analysis. Table 9 re-estimates column 5 from Tables 2 and 3 but adding location variables. Specifically, this specification adds a dummy for scientists located in the home country in year t , a second dummy for scientists located in a third (non-home, non-US) country within the same region as the home country (in year t), and a third dummy for scientists located in a third country outside of the home country region. The number of observations falls because our dataset does not contain information on our scientists' whereabouts in every year post-PhD.

The specification in Table 9, columns 1 and 2, shows that the "Fulbright premium" on home-country citations per article declines substantially in magnitude and is no longer significant at the 5% level after controlling for location. This suggests that the Fulbright premium is primarily due to being located in the home country. In Column 1, the citation boost from being located in the home country instead of the US is significant and large. Not only does locating in a low-income home country instead of in the US increase home country citations, but so does locating in a high-income home country, although being in a low-income home country has a significantly larger impact (an increase in home-country citations of 107% and 266% for high-income and low-income countries, respectively). We conclude that the reason that Fulbrights were more likely to be cited by home country authors was partly due to their greater likelihood of being located in the home country, and partly due to the greater impact of location in low-income home countries.²⁰

There are even larger differences between originating in a poor and rich home country,

²⁰ The hypothesis of equality of the low-income and high-income location coefficients is rejected at the 10% level with a p-value of 0.08.

however, when the dependent variable is citations by US researchers. In Column 2 we observe a negative and statistically significant coefficient on the dummy for being located in a low-income home country instead of being located in the US, but a statistically insignificant coefficient (with a point estimate close to zero) for the dummy for being in a high-income home country.

Scientists who return home to a high-income country are not cited significantly less per article by US researchers than those living in the US, while those who return to a low-income country *are* cited significantly less (a 44% reduction in citations, significant at the 1% level). Those located in a third country not near the home country are less likely to be cited by the US than those residing in the US.

The effects of location on backward citations are somewhat different. Being located in the home country increases citations to the home country substantially. Interestingly, there is a significant positive effect of Fulbright status on backward citations to the home country, even after controlling for location. This is not true of backward citations to the US, which are negatively associated with being located in the home country as well as the home region. This effect appears to be driven mainly by scientists located in low-income countries (Column 8).

Conclusions

In this paper, we examine the impacts of policies that require foreign-born, U.S.-trained Ph.D. students to leave the U.S. upon completion of their studies. We ask whether such policies affect knowledge diffusion to home countries and to the U.S., as measured by citations to published articles in science and engineering journals. We track the post-Ph.D. careers of 249 recipients of the Foreign Fulbright Fellowship (who are required to leave the U.S. after the completion of their doctoral studies), and 249 similar foreign-born “control” scientists (who are not subject to return requirements). On average, scientific articles by Fulbrights subject to return

requirements are not cited more frequently in their home countries than articles by controls. However, on a per-article basis, there is a “Fulbright premium” in which Fulbrights from low-income countries are cited more than twice as much at home as controls from low-income countries. Articles by Fulbrights from high-income countries are generally not cited significantly more often at home than controls from high-income countries. When we add information on scientists’ actual locations to the regression, we find that the “Fulbright premium” in forward citations is primarily explained by location. The larger positive “Fulbright premium” for low-income home-country citations appears to be explained by the fact that the return requirements have a much bigger impact on the location choices of scientists from low-income countries, increasing their probability of returning home by 46 percentage points relative to controls (and controlling for researcher productivity and home-country science base). It also reflects a greater impact of physical location on citations from low-income countries.

We also find that Fulbrights from both low-income and high-income countries are significantly more likely to cite articles from those countries. Fulbrights from countries with weak science bases in their fields of study are also significantly less likely to cite articles from the US.

We conclude that requiring scientists to return to home countries redirects their focus towards science produced at home. For high-income countries, this redirection does not appear to come at a cost: rates of US citation to and from papers by high-income Fulbrights are statistically indistinguishable from controls in all other respects, and are sometimes higher than controls. In contrast, when the home country has a weak science base, returning researchers appear to lose access to information on science produced in the US. Thus, scientists subject to return requirements contribute more to research in low-income home countries, but appear to be less

informed about cutting-edge research outside the home country. This suggests that return requirements in low-income countries should be combined with policies designed to enhance access to scientific information produced abroad. For example, subsidizing the cost of journal subscriptions, or providing grants for travel to conferences, may help improve access to information for researchers in low-income countries. Which specific policies may be most effective is a topic for future research.

Figure 1

**Fulbright-Control Difference in Citations from the Home Country
by years since PhD (controlling for covariates)**

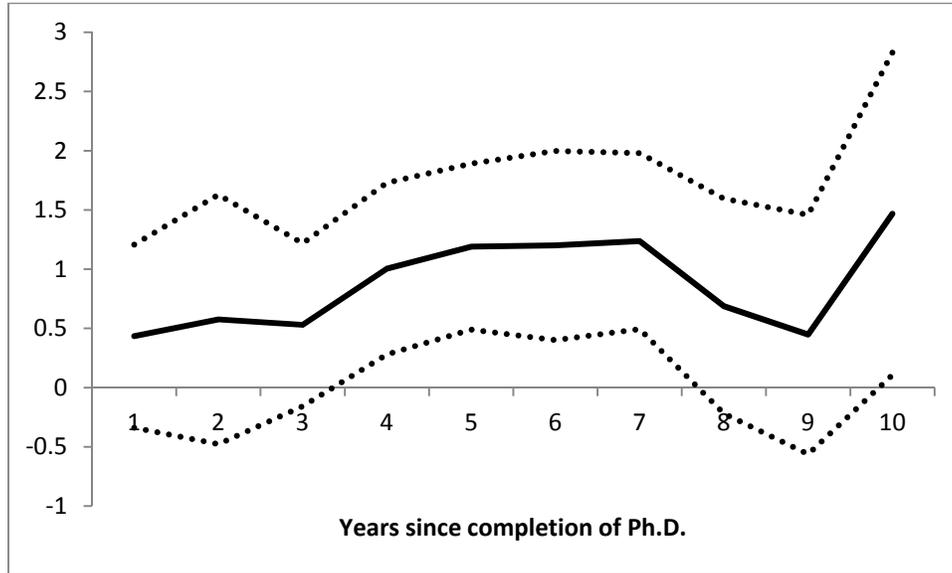


Figure 2

**Fulbright-Control Difference in Citations from the USA
by years since PhD (controlling for covariates)**

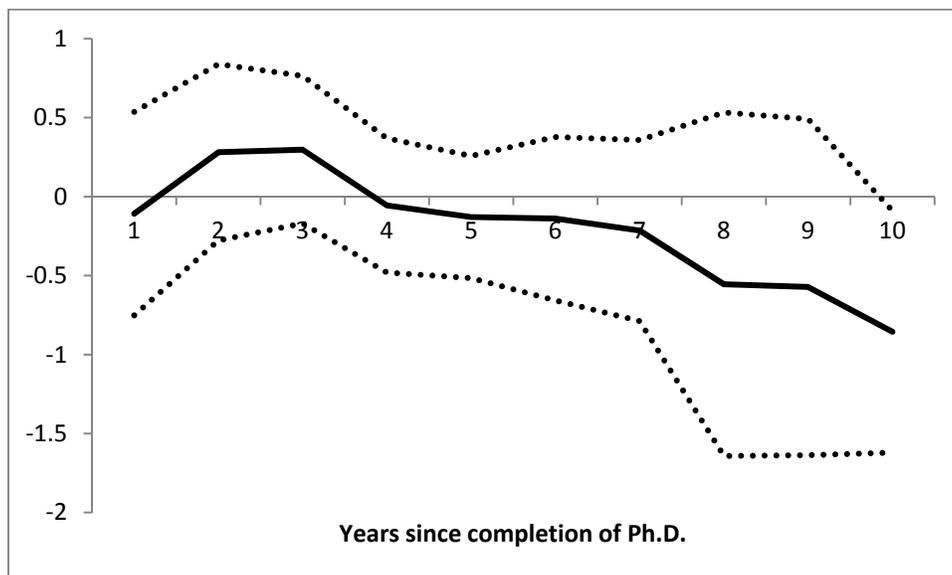


Figure 3
Fulbright-Control Difference in Scientists Citing Articles (Backward Citations) from the Home Country, by years since PhD (controlling for covariates)

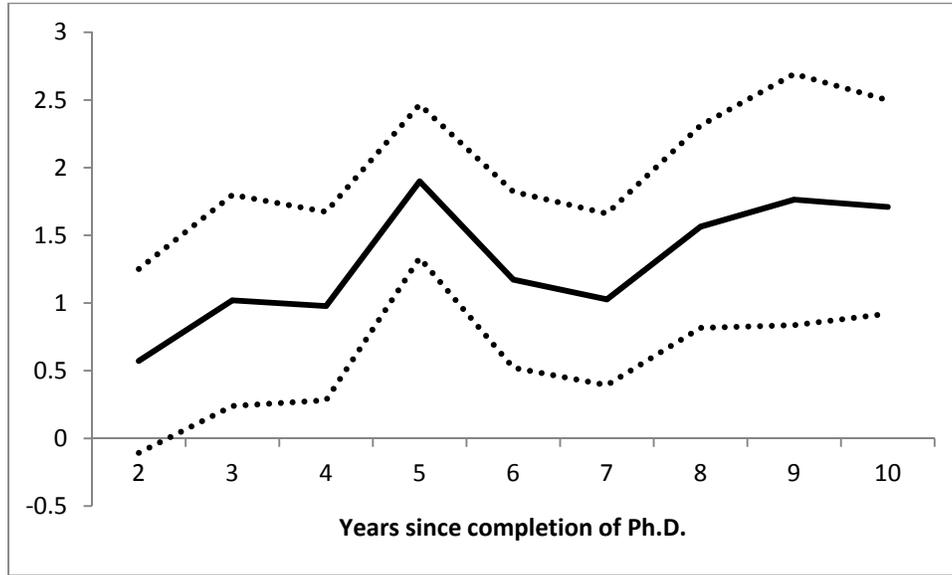
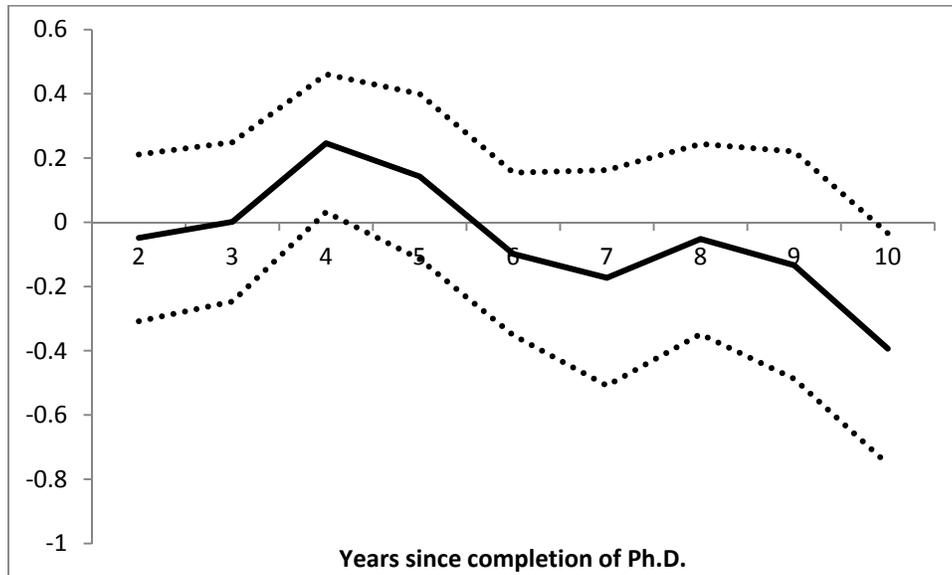


Figure 4
Fulbright-Control Difference in Scientists Citing Articles (Backward Citations) from the US, by years since PhD (controlling for covariates)



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Table 1: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Number of citations in year T to articles published in year t from home country	0.053	0.370	0	11
Number of citations in year T to articles published in year t from USA	0.741	3.709	0	151
Number if home-country citations excluding regional journals	0.052	0.368	0	11
Number of US citations excluding regional journals	0.739	3.706	0	151
Number if home-country citations excluding collaborations with main advisor	0.039	0.330	0	11
Number of US citations excluding collaborations with main advisor	0.538	3.597	0	151
Number of backward citations to home country in year t	6.970	19.506	0	411
Number of backward citations to USA in year t	0.411	2.725	0	74
Number of backward citations to home country excluding collaborations with main advisor	0.371	2.691	0	74
Number of backward citations to USA excluding collaborations with main advisor	4.696	17.801	0	411
Fulbright dummy	0.498	0.500	0	1
Fulbright from a country >75th pctl GDP per capita	0.195	0.396	0	1
Fulbright from a country <75th pctl GDP per capita	0.303	0.460	0	1
Scientist from a country <75th pctl GDP per capita	0.602	0.490	0	1
Publications by scientist i in year t	0.800	1.386	0	8
In Number of publications in scientist i's field in home country in citing year	6.272	1.870	0	10.801
Share of scientist's publications in high-impact journals	0.160	0.341	0	1
Citations per publication in scientist I's home country in 2000	10.504	6.899	0	154.75
Pre-graduation citations to home country	1.307	14.044	0	294
Female	0.228	0.419	0	1
Percentile Rank of Ph.D. program	0.317	0.250	0.009	0.958
Year of citing publication	2003.889	2.690	1992	2007
Year of cited publication	1999.777	2.987	1991	2006

Table 2: Citations from home country in T to scientist i's articles published in year t
Poisson regressions with dummies for field, year of Ph.D., citing year, and citation lag (T-t)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fulbright	0.0193 (0.327)	0.815** (0.388)	0.756*** (0.247)				
Fulbright from country >75th ptile GDPpc				0.658* (0.390)	0.445 (0.293)		
Fulbright from country <75th ptile GDPpc				0.927** (0.417)	1.174*** (0.352)		
Home country <75th ptile GDPpc				-1.147*** (0.297)	-0.917*** (0.305)		
Fulbright from country >median articles per capita in field						0.409 (0.293)	
Fulbright from country <median articles per capita in field						1.334*** (0.342)	
Home country <median articles per capita in field						-1.085*** (0.286)	
Fulbright from country >median cites per article in field							0.360 (0.315)
Fulbright from country <median cites per article in field							1.030*** (0.299)
Home country <median cites per article in field							-0.810*** (0.266)
ln Publications in scientist i's field in home country in citing year		0.778*** (0.145)	0.472*** (0.103)	0.680*** (0.112)	0.431*** (0.0899)	0.437*** (0.0908)	0.421*** (0.0985)
ln Publications by scientist in cited year			1.068*** (0.164)		0.958*** (0.171)	0.948*** (0.168)	0.966*** (0.169)
1 if female	-1.038*** (0.283)	-1.293*** (0.301)	-0.676*** (0.188)	-1.409*** (0.284)	-0.713*** (0.175)	-0.731*** (0.177)	-0.679*** (0.182)
ln Rank of PhD program	-0.178 (0.149)	-0.230** (0.102)	-0.190** (0.0902)	-0.163* (0.0901)	-0.200** (0.0895)	-0.209** (0.0913)	-0.195** (0.0949)
Constant	-5.255*** (0.583)	-10.80*** (1.360)	-8.410*** (0.845)	-9.409*** (1.007)	-7.702*** (0.746)	-7.698*** (0.761)	-7.568*** (0.907)

N. obs. = 24,657. Robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Citations from USA in T to scientist i's articles published in year t
Poisson regressions with dummies for field, year of Ph.D., citing year, and citation lag (T-t)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fulbright	-0.133 (0.284)	-0.152 (0.269)	-0.0426 (0.137)				
Fulbright from country >75th pctile GDPpc				0.361 (0.338)	0.175 (0.176)		
Fulbright from country <75th pctile GDPpc				-0.810*** (0.271)	-0.440** (0.223)		
Home country <75th pctile GDPpc				-0.469* (0.275)	-0.102 (0.216)		
Fulbright from country >median articles per capita in field						0.178 (0.173)	
Fulbright from country <median articles per capita in field						-0.412* (0.221)	
Home country <median articles in field						-0.112 (0.226)	
Fulbright from country >median cites per article in field							0.205 (0.185)
Fulbright from country <median cites per article in field							-0.306 (0.203)
Home country <median cites per article in field							-0.0422 (0.197)
In US publications in field in citing year		0.502* (0.272)	0.196 (0.124)	0.481** (0.229)	0.172 (0.124)	0.144 (0.121)	0.148 (0.120)
In Publications by scientist in cited year			1.406*** (0.147)		1.304*** (0.127)	1.307*** (0.128)	1.337*** (0.134)
1 if female	-0.704** (0.330)	-0.649** (0.301)	-0.123 (0.192)	-0.778*** (0.300)	-0.142 (0.179)	-0.185 (0.188)	-0.141 (0.182)
In Rank of PhD program	-0.263* (0.139)	-0.256** (0.125)	-0.240*** (0.0674)	-0.134 (0.0997)	-0.199*** (0.0623)	-0.192*** (0.0635)	-0.208*** (0.0657)
Constant	-2.233*** (0.514)	-7.388** (3.098)	-4.379*** (1.319)	-6.571*** (2.480)	-3.810*** (1.265)	-3.467*** (1.236)	-3.677*** (1.278)

N. obs. = 24,657. Robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Citations from home country: Robustness

Poisson regressions with dummies for sector (academic/private/public), field, year of Ph.D., citing year, and citation lag (T-t)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Adding sector dummies & country field strength		Only Global Journals		Excl. Reg. Journals & Agri/Enviro	Excl. Reg. Journals; Controlling for pregrad cites to home	Controlling for journal impact	Controlling for citations from other countries	Dropping collaborations w advisor	<90th pctile of cites
Fulbright from country >75th pctile GDPpc	0.484*	0.391	0.388	0.251	0.148	0.264	0.406	0.268	0.931***	-0.0755
	(0.279)	(0.269)	(0.275)	(0.269)	(0.317)	(0.267)	(0.279)	(0.253)	(0.272)	(0.285)
Fulbright from country <75th pctile GDPpc	1.179***	1.136***	1.102***	1.137***	1.221***	1.101***	1.149***	1.447***	1.025**	1.274***
	(0.347)	(0.329)	(0.332)	(0.292)	(0.335)	(0.296)	(0.329)	(0.339)	(0.400)	(0.354)
Home country GDP p.c. below 75th percentile	-0.857***	-0.599**	-0.563*	-0.485*	-0.359	-0.448	-0.600**	-0.739**	0.0925	-0.897**
	(0.313)	(0.293)	(0.291)	(0.291)	(0.332)	(0.296)	(0.294)	(0.314)	(0.290)	(0.348)
In Publications in scientist i's field in home country in citing yr	0.984***	0.937***	0.954***	1.056***	1.177***	1.012***	0.923***	-0.0114	1.339***	1.031***
	(0.182)	(0.177)	(0.182)	(0.164)	(0.185)	(0.186)	(0.179)	(0.182)	(0.135)	(0.269)
In Publications by scientist in cited year	0.429***	0.404***	0.399***	0.449***	0.470***	0.432***	0.397***	0.442***	0.314***	0.433***
	(0.0860)	(0.0869)	(0.0879)	(0.0872)	(0.0946)	(0.0863)	(0.0900)	(0.0791)	(0.0876)	(0.0960)
Citations per Publication in home country in field in citing year		0.0403***	0.0411***	0.0516***	0.0546***	0.0508***	0.0394***	0.0187	0.0430***	0.0135
		(0.0112)	(0.0104)	(0.0102)	(0.0105)	(0.0106)	(0.0119)	(0.0200)	(0.00771)	(0.0211)
Cites to home-country articles in pregrad pubs						0.0111				
						(0.0175)	0.283			
Share of pubs in high-impact journals							(0.191)			
								0.754***		
In Citations from other countries								(0.0804)		
	-7.753***	-8.442***	-8.421***	-9.227***	-9.564***	-9.076***	-8.513***	-7.791***	-9.865***	8.383***
Constant	(0.729)	(0.749)	(0.764)	(0.839)	(0.979)	(0.871)	(0.772)	(0.644)	(0.795)	(1.173)
	0.484*	0.391	0.388	0.251	0.148	0.264	0.406	0.268	0.931***	-0.0755
Sector dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Broad /Narrow Field	Broad	Broad	Broad	Narrow	Narrow	Narrow	Broad	Broad	Broad	Broad
Observations	24,657	24,657	24,657	18,750	24,657	24,657	24,657	22,818	22,161	24,657

All specifications include controls for gender and rank of PhD program. Coefficients of these controls available upon request. Robust standard errors, clustered by scientist, in parentheses. *** p<0.01,

** p<0.05, * p<0.1

Table 5: Citations from US: Robustness

Poisson regressions with dummies for sector (academic/private/public), field, year of Ph.D., citing year, and citation lag (T-t)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Adding sector dummies	Only Global Journals		Excl. Reg. Journals & Agri/Enviro	Excl. Reg. Journals; Controlling for pregrad cites to home	Controlling for journal impact	Controlling for other citations	Dropping collaborations with advisor	<90th pctlile of cites
Fulbright from country >75th pctlile GDPpc	0.260 (0.174)	0.264 (0.176)	-0.0824 (0.154)	-0.0340 (0.165)	-0.0747 (0.163)	0.307* (0.166)	-0.223 (0.149)	0.863*** (0.270)	-0.470*** (0.156)
Fulbright from country <75th pctlile GDPpc	-0.413* (0.217)	-0.414* (0.218)	-0.285 (0.190)	-0.332 (0.229)	-0.289 (0.193)	-0.365* (0.211)	-0.240** (0.115)	-0.495 (0.336)	-0.0436 (0.139)
Home country GDP p.c. below 75th percentile	0.0712 (0.238)	0.0789 (0.239)	-0.0722 (0.197)	0.00862 (0.208)	-0.0599 (0.217)	0.0880 (0.213)	0.0267 (0.132)	0.438 (0.337)	-0.320** (0.143)
In Publications by scientist in cited year	1.400*** (0.104)	1.402*** (0.104)	1.412*** (0.0962)	1.446*** (0.106)	1.400*** (0.103)	1.406*** (0.108)	0.186* (0.106)	1.561*** (0.104)	0.795*** (0.136)
In US publications in field in citing year	0.142 (0.122)	0.144 (0.123)	0.691*** (0.175)	0.719*** (0.188)	0.689*** (0.179)	0.0130 (0.110)	0.0145 (0.0720)	0.0988 (0.202)	-0.125 (0.0955)
Cites to home-country articles in pregrad pubs					0.00290 (0.0127)				
Share of pubs in high-impact journals						0.855*** (0.163)			
In Citations from other countries							1.015*** (0.0389)		
Constant	-3.926*** (1.258)	-3.968*** (1.270)	-9.073*** (1.750)	-9.394*** (1.894)	-9.039*** (1.792)	-128.1** (53.44)	-1.641** (0.737)	-5.672*** (2.024)	-0.237 (0.989)
Sector dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y
Broad or narrow Field Dummies	Broad	Broad	Narrow	Narrow	Narrow	Broad	Broad	Broad	Broad
Observations	24,657	24,657	24,657	18,750	24,657	24,657	24,657	22,818	22,161

Control variables for gender, rank of PhD program also included. Coefficients available upon request. Robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Backwards citations to home country in scientist i's articles published in year t
Poisson regressions with dummies for field, year of Ph.D., citing year and sector of employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
							Excluding collaborations with Advisor		
Fulbright	0.329 (0.384)	1.173** (0.459)	1.228*** (0.267)						
Fulbright from country >75th ptile GDPpc				1.027*** (0.310)			1.211*** (0.322)		
Fulbright from country <75th ptile GDPpc				1.334*** (0.394)			1.286*** (0.411)		
Home country <75th ptile GDPpc				-0.573 (0.381)			-0.389 (0.392)		
Fulbright from country >median articles per capita in field					0.951*** (0.304)			1.105*** (0.318)	
Fulbright from country <median articles per capita in field					1.497*** (0.388)			1.445*** (0.412)	
Home country <median articles per capita in field					-0.963*** (0.362)			-0.812** (0.386)	
Fulbright from country >median cites per article in field						0.856** (0.333)			1.028*** (0.347)
Fulbright from country <median cites per article in field						1.412*** (0.305)			1.402*** (0.328)
Home country <median cites per article in field						-0.993*** (0.304)			-0.863*** (0.332)
In Number of publications in scientist i's field in home country in year t			1.255*** (0.120)	1.190*** (0.132)	1.165*** (0.125)	1.125*** (0.124)	1.240*** (0.134)	1.211*** (0.125)	1.172*** (0.122)
In Publications by scientist in cited year		0.798*** (0.202)	0.429*** (0.0922)	0.369*** (0.0794)	0.339*** (0.0794)	0.335*** (0.0821)	0.359*** (0.0866)	0.324*** (0.0869)	0.321*** (0.0897)
1 if female	-0.826*** (0.320)	-1.059*** (0.360)	-0.482** (0.244)	-0.498** (0.228)	-0.513** (0.225)	-0.462** (0.226)	-0.577** (0.249)	-0.588** (0.244)	-0.546** (0.245)
In Rank of PhD program	0.00974 (0.202)	-0.0727 (0.119)	-0.0792 (0.0942)	-0.0658 (0.101)	-0.0612 (0.102)	-0.0557 (0.0993)	-0.0559 (0.112)	-0.0516 (0.113)	-0.0495 (0.108)
Constant	-2.715*** (0.941)	-8.352*** (1.813)	-6.112*** (0.918)	-5.297*** (0.850)	-4.904*** (0.856)	-4.728*** (0.845)	-5.707*** (0.911)	-5.250*** (0.926)	-5.110*** (0.909)

N. Obs. = 4,556. Robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Backwards citations to USA in scientist i's articles published in year t
Poisson regressions with dummies for field, year of Ph.D., citing year and sector of employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
							Excluding pubs with advisor		
Fulbright	-0.321*	-0.103	-0.0922						
	(0.169)	(0.126)	(0.0713)						
Fulbright from country >75th ptile GDPpc				-0.0341			0.0368		
				(0.108)			(0.143)		
Fulbright from country <75th ptile GDPpc				-0.157			-0.185		
				(0.103)			(0.141)		
Home country <75th pctl GDPpc				0.0215			0.0185		
				(0.109)			(0.139)		
Fulbright from country >median articles per capita in field					0.0321			0.132	
					(0.102)			(0.132)	
Fulbright from country <median articles per capita in field					-0.222**			-0.293**	
					(0.104)			(0.148)	
Home country <median articles per capita in field					0.0593			0.0650	
					(0.108)			(0.138)	
Fulbright from country >median cites per article in field						0.0934			0.188
						(0.113)			(0.147)
Fulbright from country <median cites per article in field						-0.208**			-0.240*
						(0.0859)			(0.126)
Home country <median cites per article in field						0.123			0.108
						(0.102)			(0.139)
In Publications by scientist in cited year			1.207***	1.201***	1.197***	1.214***	1.244***	1.238***	1.255***
			(0.0626)	(0.0606)	(0.0593)	(0.0575)	(0.0675)	(0.0665)	(0.0680)
Ln Articles published in field in US in citing year		0.0354	-0.105	-0.106	-0.115*	-0.105	-0.0859	-0.104	-0.0919
		(0.131)	(0.0652)	(0.0656)	(0.0648)	(0.0645)	(0.0988)	(0.0964)	(0.0956)
1 if female	-0.339*	-0.283*	0.0303	0.0249	0.0160	0.0168	0.0531	0.0340	0.0422
	(0.193)	(0.162)	(0.105)	(0.106)	(0.105)	(0.102)	(0.130)	(0.128)	(0.127)
Ln Rank of PhD program	-0.0375	0.0527	-0.0720**	-0.0646*	-0.0566	-0.0608*	-0.0829*	-0.0686	-0.0772*
	(0.0925)	(0.0788)	(0.0336)	(0.0359)	(0.0355)	(0.0344)	(0.0461)	(0.0451)	(0.0437)
Constant	1.507***	2.075	1.889***	1.931***	2.029***	1.853***	0.428	0.635	0.437
	(0.385)	(1.428)	(0.664)	(0.671)	(0.660)	(0.657)	(0.988)	(0.947)	(0.938)

N. Obs. = 4,556. Robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 8: Effects of Fulbright Status on Location

Linear probability regressions with dummies for sector (academic/private/public), field, year of Ph.D. and year. In column (1), the dependent variable is equal to 0 if location is US and 1 if the location is home. In column (2), the dependent variable is equal to 0 if location is US and 1 if the location is a third (non-home country).

	(1)	(2)
Dependent variable:	Located at Home	Located elsewhere abroad
Fulbright from country >75th pctl GDPpc	0.268*** (0.0633)	0.269*** (0.0725)
Fulbright from country <75th pctl GDPpc	0.462*** (0.0468)	0.194*** (0.0546)
Home country GDP p.c. below 75th percentile	-0.0948 (0.0598)	-0.0218 (0.0448)
In Publications by scientist	-0.0749** (0.0326)	-0.0914*** (0.0233)
In Publications in home country in field	0.00736 (0.0115)	0.0102 (0.0112)
Citations per Document	-0.00182 (0.00246)	0.000456 (0.00249)
1 if female	0.0142 (0.0484)	0.0284 (0.0504)
In Rank of PhD program	-0.0217 (0.0183)	-0.0374** (0.0180)
Constant	0.194 (0.129)	0.0213 (0.131)
Observations	3,844	2,538
R-squared	0.233	0.153

Robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 9: Location and citations

Poisson regressions with dummies for sector (academic/private/public), field, year of Ph.D., citing year, and citation lag (T-t)

	(1)	(2)	(3)	(4)
Dependent variable	Forward citations from home	Forward citations from USA	Backward citations to home	Backward citations to USA
Fulbright	0.327* (0.188)	0.0532 (0.127)	0.804*** (0.212)	0.0132 (0.0723)
Located in High-income Home country	0.735*** (0.224)	-0.0740 (0.194)	0.887*** (0.227)	-0.178 (0.137)
Located in Low-income Home country	1.316*** (0.304)	-0.587*** (0.195)	1.304*** (0.413)	-0.350*** (0.103)
Low-income Home country	-0.806*** (0.261)	-0.256 (0.182)	-0.641** (0.312)	0.00709 (0.0929)
Located in home region	0.412 (0.377)	-0.354 (0.300)	-0.512 (0.394)	-0.436*** (0.143)
Located outside US in non-home region	-0.552 (0.424)	-1.064*** (0.284)	-0.565 (0.420)	-0.253 (0.192)
In Publications by scientist	1.002*** (0.149)	1.280*** (0.134)	1.211*** (0.0968)	1.151*** (0.0618)
In Publications in home country or US	0.457*** (0.0955)	-0.147 (0.177)	0.383*** (0.0749)	-0.104 (0.0642)
Observations	23,371	23,371	4,341	4,341

Robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Control variables for gender, rank of PhD program, field, year, year of PhD, citation lag, and sector of job included. Coefficients available upon request.