Do Return Requirements Increase International Knowledge Diffusion?

Evidence from the Fulbright Program

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Abstract: A large percentage of the STEM doctoral recipients at US universities are foreign-born, and most are still in the US ten years after PhD receipt. This has led to concern in sending countries about "brain drain" and to policies encouraging return migration. We ask whether such policies increase knowledge diffusion to home countries, as measured by citations to articles in STEM journals. We track the post-PhD careers of 249 Fulbright Fellowship recipients who are required to leave the US after PhD receipt and 249 similar foreign-born "control" scientists not subject to return requirements. We find that articles by Fulbright Fellows from countries with a weak science base are cited more frequently in their home countries than articles by controls, and that this is due to the fact that they are more likely to locate in their home country. In addition, all Fulbrights direct their own citations towards home-country articles at a higher rate than controls. Overall, the results suggest that the return requirements mainly benefit countries that have weak scientific environments.

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1. Introduction

Predictions about global shortages of skilled workers have led to prescriptions for policies to enable countries to compete in the "global war for talent."[1] Policies specifically designed to attract top scientists have been created in countries like the UK, Canada and Australia.[2] In other countries, efforts have focused on encouraging the return of scientists who have left their home countries for studies or employment abroad.[3] Despite investments in these programs, their effects are not well understood, and some scholars have argued that highly-skilled expatriates contribute substantially to economic growth in their home countries even while living abroad. Saxenian (2002a) claims 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."

Our understanding of the effects of the mobility of scientists on the diffusion of knowledge is limited because a scientist's decision to move from one location to another is endogenous. Most scientists prioritize research opportunities when making decisions about whether to move to a new location.[4] Those who choose to return home *of their own volition* may have research interests more aligned with their home country or denser collaborative networks within their home country; on the other hand, they may have been unable to obtain an academic job outside their home country. Thus, a source of exogenous variation in location is necessary to identify the impact of location on scientific outcomes. In this paper, we examine a sample of scientists of foreign origin who obtained PhDs at US universities but were forced by visa requirements associated with the Fulbright Fellowship to return to their home countries. We compare these scientists to a group of otherwise similar scientists of foreign origin (who graduated from the same programs at around the same time) who were not subject to return requirements.

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[1] A recent McKinsey report estimates that advanced economies will face a shortfall of 16 to 18 million college-educated workers by the year 2020 (Dobbs et al. 2012)

[2] These include the Tier 1 Exceptional Talent Scheme in the UK, the Canada Research Chairs Program in Canada, and the Australian Research Council's Federation Fellowships, among others.

[3] The Chinese Ministry of Education and National Research Council encouraged expatriate scientists to return through programs that supplement salary and/or offer research funding. Argentina's Ministry of Science and Technology has the RAICES program that helps cover moving costs for those who return home permanently (Jonkers 2008).

[4] A recent *Nature* survey found 44.7% of scientists rated "increased availability of research funding" a very important determinant of whether they locate abroad, and 39% rated it quite important (Van Noorden 2012).

To focus on the impact of returning scientists on the diffusion of scientific knowledge, we ask whether the research of US-educated scientists who are required to return to their home countries has a larger impact in the home countries than it would if they were allowed to remain in the US. We also ask whether US-based scientists lose access to knowledge generated by US-educated scientists who leave the country, and whether the scientists' own knowledge acquisition is affected by their location. To correct for any additional unobserved heterogeneity that may exist after conditioning on Fulbright status we control for the number of citations to home-country articles in the scientist's pre-graduation research output (a proxy for pre-existing interest in home-country research). Specifications also control for variation in countries' science base and for scientific field. Results are robust to controlling for geographic region of origin and sector of employment.

Our results show that the effect depends on the level of development of science in the home country. Scientific articles by Fulbright Fellows from low-science countries– countries with a below-median number of articles in the field published per capita – are cited more frequently in their home countries than articles by controls, and this is due to the fact that they are more likely to locate in their home country than Fulbrights from high-science countries or controls. Citations from high-science home countries are not significantly different for Fulbrights and controls. Thus, while previously we showed that a Fulbright from a low-science country publishes fewer papers (Kahn and MacGarvie, 2011), each paper has a bigger impact at home. Moreover, backward citations to the home country by Fulbrights from both high- and low-science countries increase over time relative to controls.

Is there a corresponding loss of this scientific knowledge for the US? To investigate this, we examine forward citations to articles by Fulbrights and controls from US-based scientists. We find weak evidence that Fulbrights from low-science countries are cited less by the US (depending on the specification) . In addition, articles by Fulbrights display similar amounts of backward citations to articles by US-based authors for about eight years post-PhD, after which these references seem to fall. There is therefore some downside to return requirements for home countries, in terms of an eventual reduction in exposure and access to US science.

The major result, however, is that return requirements strengthen knowledge diffusion to the home country. This does not rule out the possibility of "brain circulation" with respect to knowledge diffusion from compatriots who received US PhDs and remained in the US. Indeed, we find that papers by foreigners who received US PhDs and remained in the US obtained a higher proportion of potential citations from their home countries than from third countries. Nevertheless, the much stronger impact of scientists who do return home suggests that return requirements substantially increase the diffusion of knowledge to countries with less developed scientific environments.

2. Literature Review

In the US, international students make up a large percentage of the doctorates granted in Science, Technology, Engineering and Mathematics (STEM). This percentage has steadily increased in recent decades, rising by 49% between 1983 and 2009 (NSF Science and Engineering Indicators 2006, 2012). Most of these students remained in the US five and ten years after the completion of their degrees (Bound, Turner and Walsh 2009, Finn 2010, 2012). However, 5-year stay rates of international students have declined since 2005 (Finn 2009, 2012, NSF 2012). Fields differ: Gaule (2011) finds that only 9% of foreign-born academic chemists in the US return to their home country during their professional career. The foreign-born who remain in the US have been shown to have made disproportionately large contributions to US science (Stephan and Levin 2001) compared to natives.

A second body of research documents the positive externalities to scientific diffusion as a consequence of geographic proximity. Jaffe and Trajtenberg (1999) identify “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. Boudreau et al. (2014) find that randomizing the people with whom scientists had face-to-face interactions at a conference affected rates of subsequent collaboration. Agrawal, Kapur, and McHale (2007) found 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. 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 US or other high-science countries.

Another set of papers, however, points to the diffusion of knowledge through long-lasting social ties that do not require geographic propinquity. Saxenian (2002b) showed that half of surveyed immigrant entrepreneurs in Silicon Valley have business activity in their home countries and over 80% share information about technology with acquaintances in their home countries. Parthasarathi (2006) found that Silicon Valley-based Indian expatriates helped develop

India's IT industry. Using exogenous variation in migration quotas, Kerr (2008) found that co-ethnicity appears to spur knowledge flows between inventors, with non-US inventors citing US inventors of the same ethnicity 50% more often. Agrawal, Cockburn, and McHale (2006) both developed a model and showed empirically that when an inventor moves to a new location, knowledge flows disproportionately back to the inventor's *prior* location. Similarly, Ganguli (2013) finds that the emigration of Soviet scientists after the fall of the USSR increased the number of citations to Soviet-era papers by authors in their new locations.

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 that the productivity of German scientists was affected by the expulsion of their Jewish colleagues, while Moser, Voena and Waldinger (2013) show that this emigration of Jewish scientists from Germany to the US 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 are required to return to their home countries transfer the information they acquired during their studies about US scientific and technological knowledge. Further, we will test whether, as suggested by prior work, scholarly relationships that develop in the course of doctoral study persist when doctoral recipients move to a different location.

3. Data and Methods

3.1 Identifying Fulbrights and Controls

The Fulbright Foreign Student Program, primarily sponsored by the US Department of State, is the main federal program that brings students from other countries to pursue graduate study in the United States. Foreign Fulbright Scholars are awarded a J-1 student visa which stipulates that they must spend at least two years in their home country after the completion of studies before applying for a US visa that would allow them 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 US between 1993 & 2005. An Online

Appendix provides a detailed description of the construction of the match between Fulbrights and controls.[5] To summarize, using directories of Fulbright scholars published in 1993-96, we matched each Fulbright who completed a PhD in STEM to a control student who graduated within 3 years of the same Fulbright from the same institution, in the same field and, where possible, with the same advisor. 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.

The Online Appendix includes results of robustness checks in which we use alternative matching methodologies (such as propensity score matching and coarsened exact matching) to match Fulbright and control scientists. Our main findings are robust to using these alternative matching methods.

We used CVs, faculty websites, publications, and Google searches to identify locations of the scientists each year. We were able to identify locations for 37,822 of the 39,816 total person-years between PhD and 2007, the last year that we used to collect "cited" publications.

The Fulbrights in our sample were more than twice as likely as controls to have been in their home country: for 76.0% of our Fulbright sample, we found evidence that they spent some time in their home country after receiving their PhDs, compared to only 34.5% of our control group.

3.2 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, excluding self-cites. Both forward and backward citation data were provided to us by Thomson-Reuters based on their Web of Science database. 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 published article, for example by teaching and advising students, participating in conferences, consulting with industry, and so on. Our focus here is limited to published knowledge diffused to scientists who then build upon that knowledge in their own

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[5] Available at http://people.bu.edu/skahn. Kahn and MacGarvie (2014) uses this same data.

published work.

We identify the location of the citing publication as the reprint address (the address of the author one should contact when requesting a reprint of the article).[6] Most citing articles have multiple authors, potentially located in different countries. 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 for publications on Web of Science, in which the reprint author commonly was the first or last author.

Our analysis of forward citations is based on 39,816 observations, each representing a potential person/cited-year/citing-year for one of the 498 scientists (excluding self-citations). 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 source articles published by the scientist in year t.*[7]
2. *Number of (forward) citations in articles published in year T by authors in the USA, to source articles published by the scientist in year t.*

We analyze forward citations through 2010 to articles authored by the scientist beginning in the year after completion of the PhD up to and including 2007.[8]

In robustness checks, we also analyze citations excluding those to journals focused on issues relevant to the author's home region or country. Specifically, we computed:

3. *Number of (forward) citations (from home country or US) to source articles published in global journals*: We defined "global journals" as journals without the home 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* and *Tierarztliche Praxis Ausgabe Grosstiere Nutztiere.*
4. *Number of (forward) citations (from home country or US) to source articles published in global journals AND excluding those in agricultural or the environmental fields:* For this analysis, we also excluded scientists in the fields of agriculture, forestry and fisheries and in environmental sciences.

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[6] 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.

[7] Throughout this paper, we denote the cited year as t and the citing year as T.

[8] Our collection of article data began in 2008, which is why the sample is truncated in this year.

For the backward citation regressions, we collapse the citation data to the scientist/citing-year T level, thus combining all cited years. As explained later, we do this because important data about the cited year was not available before 1996. Therefore our dependent variables in these backward citation regressions are:

5. *Number of backward citations in all source articles published by the scientist in year T to authors in the scientist's country of origin.*
6. *Number of backward citations in all source articles published by the scientist in year T to articles to 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 PhD graduation up to and including 2007. As with the forward citation data, we drop self-citations and use the reprint address to identify the country of the cited article. The backward citation analysis includes 4,555 person/citing-year observations.[9]

It is possible that backward citations to 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 the US and foreign scientists, 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:

7. *Number of backward citations excluding articles co-authored with the student's main advisor:* We compute backward citations after dropping source articles with an author list that contains the surname of the primary dissertation advisor.[10]

Table 1 gives summary statistics for each of these measures of forward and backward citations.

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 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.

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[9] This does not exclude the 2728 person-years in which the scientist had no publications. We include a dummy variable for person-years with no publications. The results are comparable if we instead drop these person-years.

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

Secondly, if researchers in certain fields are overrepresented in certain countries, we may be more likely to observe citations between a scientist from that country and scientists at home despite broad field controls. 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 these possibilities in the robustness results below.

3.3 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 and Stephan (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 (home-country or USA) [11] F in year T. The denominator represents 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 in year T 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}.[12] To relax (and test) these assumptions, we model C_{itFT} as our dependent variable and include N_{it} and N_{FT} as separate explanatory variables.

Jaffe and Trajtenberg (1999) and Adams, Clemmons and Stephan (2006) model this ratio as a function of time-since-publication with a specific functional form that allows them to estimate the rates of knowledge diffusion and obsolescence. We instead use a less restrictive semi-parametric functional form. Specifically, we include a separate dummy for each value of the lag T-t (α_{T-t}). We also add controls Z_{itFT} related to the person, field, and home country at time t and dummy variables for the citing year T (α_T).

We can express the conditional expectation of the dependent variable as:

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[11] Depending on whether modeling citation frequency from the home country or from the US.

[12] This is unlikely to be the case because people publish on much narrower topics than the broader fields used to define the potentially citing articles.

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

Again, C_{itFT} is the number of forward citations made by publications in field-country F in year T to source articles written by scientist i in year t; N_{FT} is the total 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 coefficients to each equal 1 if the original specification with P_{itFT} as dependent variable is correct.[13] Note that since we control for the (log of) the number of the scientist's publications (N_{it}), this allows us to interpret all other coefficients as the impact on citations per publication.

Because citations are a discrete non-negative variable bounded by zero (a count), we use Poisson regression models with standard errors clustered by scientist to estimate the parameters of the above model.

3.4 Control variables

The empirical model implies that two key control variables are potentially cited and potentially citing articles. The specific measures for these variables are:

Potentially citing articles: In our analyses of forward citations, we control for $\mathbf{N_{FT}}$, the number of potentially citing articles published in field-country F in citing-year T. This variable comes from the Scimago Journal & Country Rank (2007) and was computed by a research team from the Universities of Granada, Extremadura and Carlos III (Madrid) using articles contained in Elsevier's Scopus database.[14]

For regressions in which the dependent variable is backwards citations, our control for the number of potential citing articles is simply the log of number of articles published by the author in citing year T.

Potentially cited articles: To control for the number of potentially *cited* articles $\mathbf{N_{it}}$, we include the natural logarithm of the number of source articles produced by the scientist in cited year t and indexed on ISI's Web of Science.

For backwards citation regressions, we control for the (log of the) number of articles published in year T in the scientist's field in his home country in citing-year T (or in the US in the case of

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[13] See Cameron and Trivedi (1998), p. 81.

[14] Retrieved April 03, 2012, from http://www.scimagojr.com. See Borja González-Pereiraa et. al. (2009) for more about this measure. 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.

citations to the US), as a reasonable proxy for the set of potentially cited articles. It is not possible to disaggregate the backward citation analysis by cited year and to control for the number of articles published in the home country in each potentially cited year, because the Scimago field/country articles data are only available for 1996 and later.

Dummy for zero cited articles: We include a dummy variable equal to 1 for observations when the scientist had no publications, i.e. when N_{it} is equal to zero. Results are also robust to dropping observations for which N_{it} equals zero.

An additional important control variable is:

Number of citations to the home country in pre-graduation articles: the pre-sample mean estimator of Blundell, Griffith and Van Reenen (1999) corrects for unobserved heterogeneity in panel data by conditioning on the mean of the dependent variable in a pre-sample period. In this paper, we take a similar approach by controlling for the number of citations to home-country articles in the scientist's articles published prior to graduation. This variable controls for the scientist's pre-existing interest in home-country research prior to possibly moving to the home country after graduation. Any remaining observed correlation between Fulbright status and citations to the home country should thus reflect the impact of return requirements on knowledge diffusion.

All of the analyses also include the following control variables Z_{itFT}:

Ranking of PhD institution: We include the (log of the) 1995 relative ranking of the US PhD institution (by field) from the National Research Council (Goldberger et al. 1995) as a control for the quality of PhD 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.

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) and using a web-based algorithm for identifying the probable genders of given names when no other information was available.[15]

Field dummies: We categorized each student by the first field listed in their (Proquest) dissertation record. These are 21 fields based on NSF classifications.

Dummies for year of PhD receipt: We include a series of dummies for ranges of the PhD year as follows: pre-1997, 97-98, 99-00, 01-02, and post-2002.

Dummies for length of lag: We include a dummy for each value of the gap between the cited-

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[15] The gender-guessing program is found at: http://www.gpeters.com/names/baby-names.php.

year t and the citing-year T in all analyses of forward citations. Since we must collapse all cited years in the backward citation analysis, these dummies are not included there.

Dummies for citing year T: : We include dummies for citing years prior to 2000, 2000-01, 2002-03, 2004-05, 2006-07, 2008-09 and 2010.

In addition, different specifications may contain the following dummy variables, both linearly and interacted with the Fulbright dummy:

Home country below the median country ranked by articles per capita in field**:** In some specifications, we include a dummy variable equal to 1 if the number of articles in the field per capita published in citing year T in the scientist's home country is less than the median value for other countries.[16] 62.6% of person/citing-year combinations (or 61.0% of the 39,816 person/citing-year/cited-year observations) are from home countries below the median articles per capita in the field. We also interact this dummy and its converse with the Fulbright dummy. We refer to these countries as low-science countries and its converse as high-science countries.

Home country below the median country ranked by forward citations per article in field**:** In some specifications, we include a dummy variable equal to 1 if the number of citations per article in the field published that year in the scientist's home country is less than the median value for other countries. 72.5% of person/citing-year combinations (or of observations) are below the median citations per publication in the field.

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. 61% of both person/cited-year combinations and of observations are in this low-income category.

Table 1 gives summary statistics for the control variables.

Finally, all specifications include either a Fulbright dummy, or two variables: the Fulbright dummy interacted with being from a low-science or low-income home country as defined by one of the above three variables, and the Fulbright interacted with being from its converse.

4. Results

4.1 Forward Citations from the Home Country

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[16] Source of numbers of articles Scimago Journal & Country Rank (2007)

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 (dependent variable 1 above). 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 potentially cited articles produced by the scientist (N_{it}) are included. Column 2 adds these two variables. Controlling for the number of the scientist's articles[17] and for the number of potentially citing articles published in the home country in the scientist's field causes the coefficient on Fulbright to become significant at the 5% level, with a coefficient that corresponds to a 63% increase (coefficient .484)[18] in the number of home-country citations. We thus conclude that articles by Fulbrights are cited more by their home country than articles by controls.[19]

Is this effect similar for those from very different types of home countries? Columns 3-4 allow the Fulbright effect to differ for those from countries that have less developed scientific infrastructures. We define these "low-science" countries as the set of countries with a below-median total number of articles per capita in the scientist's field. To ensure that we are not picking up the effect of *being from* a low-science home country, we also control for whether the scientist – whether Fulbright or control – originated in a low-science country.

Similar to the previous columns, when we do not control for potentially citing articles or for articles produced by the scientist (Column 3), there is no significant difference between Fulbrights from either kind of country. However, when we do control for these variables (Column 4), we see that Fulbrights from low-science countries have 152% (coefficient .936) more citations from the home country than do controls from low-science countries. In contrast, we see statistically insignificant effects for Fulbrights from high-science countries. We thus conclude that scientists subject to requirements to return to low-science countries are better known at home than those not required to return. This is not true for Fulbrights from high-science countries.

Column 5 uses a different measure to define the home country's scientific output, based on the country's *citations per article* in the field and cited year. This measure allows us to distinguish countries with high-quality or high-impact articles from countries that simply

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[17] Recall that this allows us to interpret other coefficients in the equation as affecting per-article citations.
[18] In Poisson regressions, the percent change is calculated as $\exp(\beta) - 1$.
[19] Marginal effects for Tables 2-7 are listed in the Online Appendix.

produce many articles. Controlling for the scientist's publications that year and for potentially citing articles, results are qualitatively similar to the original measure of the home-country's scientific output (Column 4). There is no significant difference in home-country citations to Fulbrights and controls from science-rich countries, but a highly significant difference in citations to those from low-science countries where Fulbrights are again more than twice as likely to be cited by the home country.

Do we observe similar effects when we differentiate according to the country's income level, as opposed to scientific output? Column 6 breaks Fulbrights into those above and below the 75th percentile when countries are ranked by their GDP per capita. Similar to the previous results, articles by Fulbrights from low-income countries are cited more in the home country than are articles by comparable controls, in this case 117% more (coefficient=.776). Articles by Fulbrights from rich countries are not significantly different from controls.

Comparing log likelihoods across specifications (4), (5) and (6) suggests that the differentiation by the home country's scientific output measured as number of publications (column 4) predicts citations most accurately, so we use this measure of home country development in our robustness analyses.[20]

The coefficients on the two "exposure" variables – the number of publications by the scientist and the number of publications in the field/home country in the citing year are both highly significant in all specifications in which they appear. The coefficient on the number of publications by the scientist is not significantly different from one, as predicted by the model. However, here and in later tables, its numerical value is consistently greater than one, and in some later cases is significantly different from one. This may suggest that there are increasing citation returns to publications, i.e. that scientists who publish more articles are cited more often per article, all else equal.

The coefficient on the number of publications in the field from the home country (i.e. with a home country reprint address) is also predicted to be one in the model, but instead is significantly less than one whenever the scientist's publications are also controlled for. It is quite possible that the fields we use are too broad, so that the number of potentially citing articles according to our measure is larger than the true number of potentially citing articles. It would be extremely difficult, perhaps impossible, to identify the true set of potentially citing articles for each scientist, and our measure is the best available proxy of which we are aware.

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[20] The log pseudo-likelihoods are Column 4: -5879.25; Column 5: -5888.46; Column 6: -5908.09.

Interestingly, articles by female scientists[21] are cited dramatically less often in their home countries than those by male scientists, all else equal. Not surprisingly, the higher the status of the scientist's PhD program (the lower the rank), the more citations are made by home country researchers.

In regressions not shown, we re-estimated the basic model (Column 2) controlling for the regular covariates but including separate Fulbright dummies for each year since PhD. Figure 1 graphs the pattern of the coefficients on these dummies through 10 years post-PhD along with the 95% confidence bands.[22] 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.

4.2 Forward Citations from the USA

The above results suggested that low-science and low-income home countries gain scientific knowledge when their 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 source articles published in year t by scientist i. The same specifications are included, except that the control for potentially citing articles is now all US articles in the field.

Table 3 reveals that on average, there is no significant average difference in US citations between Fulbrights and controls (Columns 1-2). Dividing by home-country type, citations from the US to scientists from high-science/high-income home countries are not different for Fulbrights than controls (Columns 3 – 6).

However, there is a negative effect (of 26%, coefficient -0.300) associated with US citations to Fulbrights from low-science countries, significant only at the 10% level, even controlling for the number of articles produced by the scientist (Column 4). Measuring the country's level of scientific strength by citations per article (Column 5) or by income (Column

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[21] This applies to columns 2, 4, 5 and 6 that control for the number of publications so other coefficients can be interpreted as the impact on citations per article.

[22] There are very few citations in our sample less than 2 or more than 10 years post-PhD, making coefficients in those ranges inaccurate.

6), the point estimate is negative and of similar magnitude, but not significant. Taken together, the diffusion advantage gained by science-poor home countries may occur at some cost in terms of less scientific knowledge in the US. An alternative or perhaps complementary interpretation is that the knowledge produced by students from low-science home countries who returned to their home countries is less relevant to scientists in the US than the knowledge produced by the students who did not return.

Intriguingly, while citations per article from home countries to females were significantly lower than to males, citations to females from the US are not. This suggests that women outside the US – but not within the US – may be at a disadvantage with respect to receiving citations when compared to men. The results on PhD rank are similar to the home country results.

As above, we re-estimated the basic model of Column 2 adding separate Fulbright dummies for each year since PhD. We graph these dummies in Figure 2. There is no clear time trend,[23] suggesting that for a sustained period, scientists' work remains equally known in the US whether they are located in their home country or abroad.

4.3 Explaining the Fulbright premium in forward citations

We have established that Fulbrights from low-science home countries have higher citation rates per article in their home country than controls. There are a number of potential reasons for this higher rate. Prior evidence on the benefits of geographic proximity on citations points to this as the most likely cause.

One potential alternative reason is that the return requirement causes Fulbrights and controls to work in different sectors. For example, Fulbrights from low-science countries may be more likely to work in academia while controls from these countries may obtain employment visas to work in industry in the US. 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 4.[24] The results are robust to adding these controls.[25]

Another possibility is that Fulbrights are disproportionately drawn from countries with particular strengths in their specific areas of research. To account for this possibility, Column 2

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[23] A test of a non-zero linear relationship over years since PhD is rejected.

[24] In 62% of Fulbrights' person-year observations, they are working in academia, in 17% they are working in government and in 21% they are working in industry. For controls, the comparable numbers are 69.5% in academia, 17% in government and 14% in industry.

[25] These dummies are not included in the rest of the specifications in Table 4, although results are similar with them.

adds narrowly-defined region dummies: the key coefficients are essentially unchanged.[26] In Column 3, we add field-specific measures of countries' research strength measured by the country's number of citations per publication in that field in the citing year. Including these controls has little effect on the coefficient on Fulbrights from low-science countries.

A different way to exclude the possibility that Fulbrights' research is more closely aligned with the research strengths of the home country is to evaluate whether Fulbrights publish at a higher rate in "global" journals (as previously defined). In Column 4 of Table 4, the dependent variable includes only citations to articles published in global journals.[27] We obtain similar results. In case the higher rate of citation in the home country is due to Fulbrights and others in the home country being more focused on agricultural and environmental topics applicable mainly in the home region, Column 5 completely excludes all scientists whose PhDs were in these fields. Here, the coefficient on Fulbrights from low-science countries increases rather than decreases: their home-country citations are 206% higher (coefficient 1.120) than that of controls.

Another possibility is that students are selected for Fulbright fellowships because they express early interest in research conducted in the home country. If so, this would be reflected in a larger number of citations made *by* the scientist to the home country in publications authored while 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 is not significantly different from zero, and including it only slightly reduces the coefficient on the low-science Fulbright, which remains significant at the 5% level.

Another possible reason that Fulbrights are more highly cited in low-science home countries, besides geographic proximity, may be that on average, the research of Fulbrights from low-science countries is simply of higher quality than that of controls or Fulbrights from high-science countries. This might be the case if Fulbright funding attracts the very best people only in poorer and science-poor countries where students have fewer other opportunities to afford graduate study or to earn a comparable degree inside the country. If so, this would also cause Fulbrights from low-income, low-science countries to receive more citations from high impact

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[26] Region categories are: Africa, China/Taiwan, Eastern Europe, Japan/Korea/Singapore, Middle East, North America, South America, Southeast Asia/Oceania, and Western Europe.

[27] We do not exclude citations *from* articles published in non-global journals.

journals and to have more highly-cited articles. Also, it would cause them to receive more citations not just from the home country, but from all countries.

We investigate this in three ways. First, Column 7 of Table 4 shows that the estimated effect of being a low-science country Fulbright is robust to controlling for the share of the scientist's articles published in high-impact journals. Second, the result from Table 3 Column 4 already indicated that Fulbrights from low-science countries receive fewer citations from the US, suggesting that these articles are not of particularly high quality. To take this one step further, 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). Not surprisingly, this variable is highly significant since it too measures the scientist's citability. Nevertheless, Fulbrights from low-science countries receive even more (although not significantly so) home-country citations than controls from low-science countries than in the base case, all else equal. Finally, in Column 9, we drop the most highly-cited 10% of articles. The coefficient for Fulbrights from low science countries is again (insignificantly) higher than in the base case, again indicating that citations to the work of higher-quality Fulbrights were not dominating the original result.

Similar robustness checks for the results on forward citations from the US can be found in Table B4 of the Online Appendix. They are consistent with Table 3, and also suggest that the marginally significant coefficient for low-science Fulbrights in Column 4 of Table 3 can be explained by the fact that these scientists publish fewer highly-cited articles on average.

4.4 Patterns in Backward Citations

Table 5 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 scientist's publications and for publications in the home country in the field, articles by Fulbrights are 190% (coefficient 1.064) more likely to cite work from the home country (Column 1). Columns 2 through 4 indicate that the effect is largest for those Fulbrights from low-science or low-income home countries, with Fulbright premia ranging from 236% to 285% (coefficients 1.213 to 1.348). However, Fulbrights from high-science or high-income home countries are also more likely than controls to cite people from the home country, with Fulbright premia between 104% and 133% (coefficients 0.715 to 0.846).

Figure 3 shows how the greater Fulbright tendency to cite home country work changes as the time since PhD receipt increases.[28] Although the pattern is noisy, on the whole, backward cites rise over time and then seem to flatten out, suggesting that Fulbrights take a few years to become aware of and/or influenced by their home country colleagues.

To round out our analysis, Table 6 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 (Column 1). Isolating those from high- v. low-science or income countries (Columns 2 - 4), the results remain small and insignificant. However Figure 4, based on estimated separate Fulbright dummies for each year since PhD, suggests that there is a negative effect of being a Fulbright on cites to the USA from Fulbrights starting about nine years after PhD. In other words, backwards citations to the US are maintained by Fulbrights for an extended period, although there is some indication that Fulbrights eventually become less aware than controls of the US literature.

It is possible that citations to 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 the US and foreign-located scientists, since the dissertation advisor may be the one acquiring and disseminating the information reflected in the citations. To better evaluate whether the scientists with return requirements are less aware of work being done in the US, we re-estimated the analyses of backwards citations *excluding* any publications where the scientist collaborated with their US PhD advisor (Columns 5-8 of Table 6). Comparing these columns to their counterparts (Columns 1-4), there are only small and insignificant changes in the coefficients due to dropping these publications.

4.5 Citations and Location

Fulbrights are more than twice as likely to be located in their home countries as controls, and almost twice as likely to be in a third country. This is shown in Table 7's linear probability models of location (where each observation is a person-year). Column 1 shows that Fulbrights are 33 percentage points more likely to be observed in home countries each year than controls (26% of whom are in their home country). They are 6 percentage points more likely to be observed in third countries than controls (8% of whom are in their home country, column 3.) While both Fulbrights from low and high-science home countries are more likely to be located at

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[28] For backward cites, this remains the time from PhD to the year of the citing article, which in this case is the article written by our scientist.

home than controls, there is a 15 percentage points (p<.01) difference between them. Only Fulbrights from high-science countries are more likely to be located in a third country (Column 4). Most of these are Europeans who may be located near but not in their home country. In estimation not shown here, we found no impact of being from a high or low-science country on the location of controls. As a result we do not differentiate between them in Table 7.

Column 6 shows that, in fact, Fulbrights from high- and low-science countries are approximately equally likely to be found *anywhere* outside the US post-PhD. Combining results, we conclude that all Fulbrights are more likely to be abroad than controls, but that those Fulbrights who are from low-science countries are more likely to be in the home country and less likely to be in third countries than Fulbrights from high-science countries.

We believe that the dominant reason that Fulbrights are more likely to be located in their home countries is the return requirements they face. To address the potential concern that Fulbrights may be different from controls in other ways that impact location despite our attempts to match them, the rest of Table 7 adds the control variables listed in the table plus dummies for field, year, and PhD year. Comparing these to the previous columns, *ceteris paribus* the difference between low and high-science countries' Fulbrights' propensities to be located at home is even higher (col. 8 difference= 22 percentage points). Also, now Fulbrights from low-science countries are significantly more likely (col. 10, 5.6 ppt.) to be located in third countries, while the difference between location in third countries of Fulbrights from high-science and controls has narrowed somewhat (to 8.4% ppt). Overall, adding control variables widened the difference between the likelihood that Fulbrights from low v. high-science countries will be located anywhere outside the US to 17.4 percentage points (Column 12).

Tables 2-7 displayed estimates of the reduced-form impact of return requirements on citations. In Table 9, we present (using Limited Information Maximum Likelihood) estimates of the causal impact of location on citations, using Fulbright as an instrument for location. In Column 1 of Table 9, the dependent variable is home country forward citations, and the endogenous variables are a dummy for being located in a "high-science" home country and a dummy for being located in a "low-science" home country. The instruments are dummies for being a Fulbright from a high-science or low-science country respectively, and control variables are similar to Table 2. This specification shows that being located in a low-science home country increases home-country citations by 0.059, which is 100% of the sample average. The coefficient associated with returning to a high-science home country is larger in magnitude, but statistically insignificant due to large standard errors. The imprecision of this latter estimate may reflect the fact that our instruments are relatively weak predictors of high-science home country location with a first stage F-statistic of only 5.29.[29] In contrast, the F-stat for low-science home location is 35.8, well above the typical cut-off value for weak instruments of 10. Thus, we are confident that there is a large positive causal impact of location on home-country citations for low-science countries; for high-science countries, our estimates are too imprecise to provide an answer either way.

Scientists might still contribute to the diffusion of science to their home-countries when they return to the home *region*, if not the home country. This is particularly common among those from Europe. In Column 2, the endogenous variables are dummies for being located in high- or low-science home *regions* and the instruments are as described above. In this specification, the first-stage F-statistics are 10.3 and 41.2 for the regressions predicting location in high-science and low-science home regions, respectively. These regressions estimate a slightly smaller effect of location in low-science home regions than countries, 0.052 citations or 88% of the sample average (p-value 0.066). Being located in a high-science home region remains not significantly associated with more home-country citations.

The rest of the columns in Table 9 present the results of specifications with the same RHS variables but different dependent variables: forward citations from the US, backward citations to the home country, and backward citations to the US. There is a large significant effect of location in the home country on the scientist's own backwards citations to home-country articles (column 5, 0.61 citations, 146 % of the average number of home-country backward citations) and an only slightly smaller effect (0.54 citations, 127%) of being located in the home *region*. There is no significant impact of location on backwards citations to high-science home countries or regions (columns 5 and 6), nor is there evidence of an effect of location on forward or backward citations from/to the US (columns 3,4,7,8).

5. Brain Circulation

Although Fulbrights' articles receive more citations from scientists in their home countries than do articles by controls, there might still be some advantages to home countries' scientists from compatriots receiving US PhDs who then remain in the US. For instance,

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[29] Table 7 Columns 6 and 12 showed that for individuals from high-science countries, Fulbright status is a strong predictor of being located *outside the US*, but since Fulbrights may choose a location outside the US other than their home country, it is a weaker predictor of location in the home country itself.

although these PhDs are cited less by the home country and cite home country work less than those who do return, it is still probable that they are more likely to be cited by and to cite articles by the home country than are American or other scientists.

Our data set is not perfectly suited to test this hypothesis. However, one indication that the home country receives some benefit from its citizens receiving a US science PhD and remaining in the US might be if these scientists are more cited by their home country than by third countries, relative to potential citations.[30] Returning to the spirit of the empirical approach, we calculate the proportion of potential citations from the home country by multiplying potentially citing papers from the home country (in the field in year T) times potentially cited papers by our scientist in year t. Similarly, we calculate the proportion of potential citations from a third country by multiplying potentially citing papers from a third country (all articles published in the field in year T minus those published in the home country and in the US) times potentially cited papers by our scientist in year t. We then calculate what proportion of home country and third country potential citations were earned by scientists in our sample who were located in the US.

We find that a scientist in our sample living in the US on average received 0.0055% of all potential citations from his or her home country but less than a third of that proportion (0.0016%) of potential citations from third countries. This suggests that home country researchers are more aware of the research of their compatriots living in the US than are third country researchers, although additional research would be necessary to eliminate alternative explanations for this result.

6. Conclusions

In this paper, we examine the impact of a policy that requires foreign-born, US-trained PhD students to leave the US upon completion of their studies. We ask how such policies affect knowledge diffusion to home countries and to the US, as measured by citations to published articles in science and engineering journals. To do this, we track the post-PhD careers of 249 recipients of the Foreign Fulbright Fellowship with return requirement and 249 similar foreign-born “control” scientists not subject to return requirements.

On average, Fulbrights subject to return requirements do not receive more home-country citations than comparable controls. However, on a per article basis (and as a proportion of the

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[30] They will surely be more likely to be cited by US articles the most due to the strong impact of location and propinquity that we (among others) have demonstrated.

maximum number of possible citations the Fulbrights could get from the home country), there is a "Fulbright premium": articles by Fulbrights are cited 63% more frequently in their home countries than articles by controls, and this premium appears to grow over time. Disaggregating, the Fulbright premium is apparent only for Fulbrights from countries with below-median articles per capita in the scientist's field ("low-science" countries). Fulbright scientists from these countries are cited 152% per article more at home than are controls from comparable low-science countries. Fulbrights from high-science countries are not cited significantly more often at home than similar controls. A variety of robustness checks confirm these basic results.

Thus, return requirements for countries with weak scientific environments do counteract brain drain. Scientific research performed by these US-educated scientists diffuses much more to home countries if the scientists are required to return home, even if only for two years. This does not rule out the possibility of "brain circulation" with respect to knowledge diffusion from compatriots who received US PhDs and remained in the US. Indeed, we find some evidence of brain circulation since in our sample, foreigners with US degrees located in the US obtained a higher proportion of potential citations from their home countries than from third countries. Nevertheless, the much stronger impact is from scientists who do return home.

Further investigation indicates that the reason that return requirements have these impacts is likely due to the increased likelihood of Fulbrights to be located in their home countries. The reason the "Fulbright premium" is present only for those from low-science countries appears to be explained by the fact that the return requirements have a much bigger impact on the location choices of scientists from low-science countries, increasing their probability of being located at home by 38 percentage points relative to controls (controlling for researcher productivity, home-country science base, field etc.) while only increasing the probability of returning home to high-science countries by 23 percentage points.

We also find that Fulbrights from both low-science and high-science countries are significantly more likely to themselves cite articles from their home countries (backwards citations) than comparable controls, with larger effects from low-science countries. Here too, the higher likelihood of a low-science country Fulbright locating in the home country makes the effect larger for these countries.

Are the Fulbright scientists' contributions to home-country science achieved at the cost of a decreased impact on US science? In some specifications, we find weak evidence that articles by Fulbrights from low-science countries receive fewer citations from the US. For Fulbrights from high-science countries, there is no reduction in citations from the US relative to controls. These findings appear to be partly explained by the fact that Fulbrights from low-science countries tend to publish in lower-impact journals and few have abnormally high citation rates. In contrast, there were a small minority of Fulbrights from high-science countries who received more than their proportional share of US citations; the rest received less than their share.

On average, Fulbrights themselves cite research by US-based authors as often as do controls. However, the time trend of these cites suggests that their tendency to cite US literature begins to deteriorate after about eight years after the PhD.

We conclude that requiring scientists to return to home countries redirects their focus towards science produced at home. These return requirements were imposed so that the home-country scientific environment would benefit from the PhD education of the Fulbright, and they have indeed accomplished this goal for countries without a strong scientific environment. Graduates returning to these countries share their knowledge with their compatriots, informing their own scientific work.

The downside of return requirements is that some researchers returning to countries with a weak science base may eventually find their work less likely to receive acknowledgement in the US and may lose some access to information on science produced in the US over time. This suggests that return requirements in low-science countries should be combined with policies designed to enhance exposure to the wider scientific world and access to scientific information produced abroad. For example, providing grants for travel to conferences, subsidizing the cost of journal subscriptions, or hosting international conferences may help increase scientific interactions between researchers in low-science countries and other scientists. Which specific policies may be most effective is a topic for future research.

Return requirements do not appear to increase knowledge diffusion to countries with a strong science base (although the requirements do increase returning scientists' citations to home-country articles). This suggests that return requirements may not be necessary to ensure the diffusion of scientific knowledge to high-science countries.

Figure 1: Fulbright Effect on Citations from the Home Country by years since PhD (controlling for covariates)

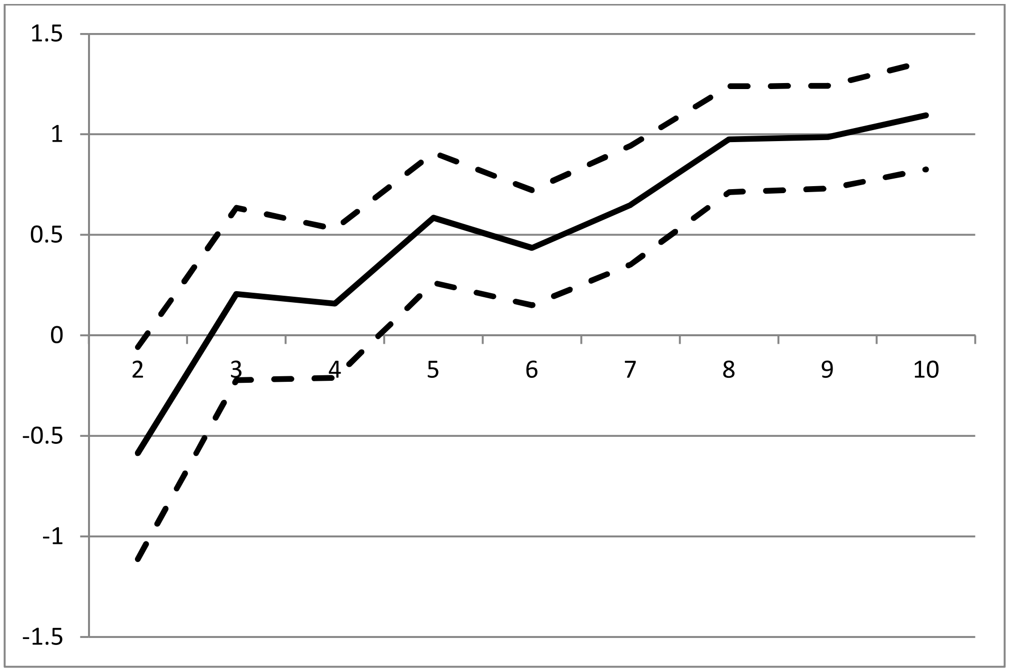

Figure 2: Fulbright Effect on Citations from the USA by years since PhD (controlling for covariates)

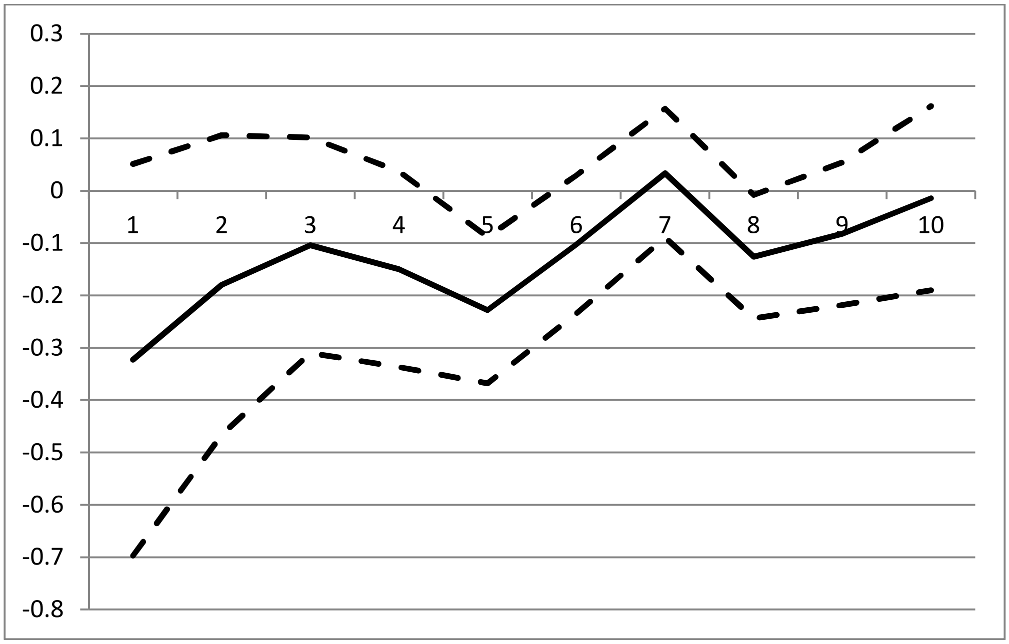

Figure 3: Fulbright Effect on Backward Citations to the Home Country, by years since PhD (controlling for covariates)

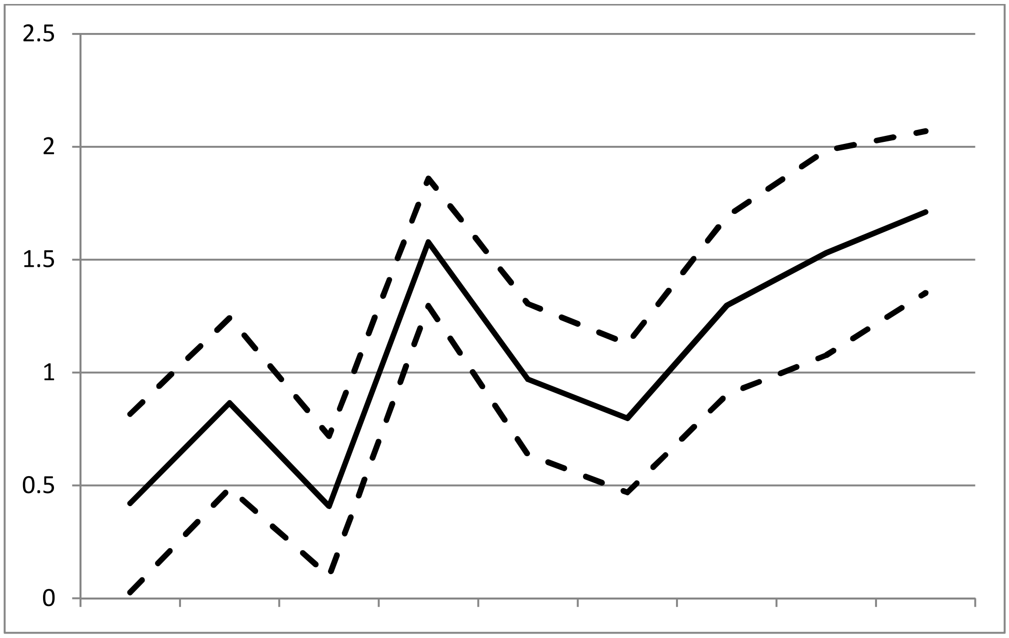

Figure 4: Fulbright Effect on Backwards Citations to the US, by years since PhD (controlling for covariates)

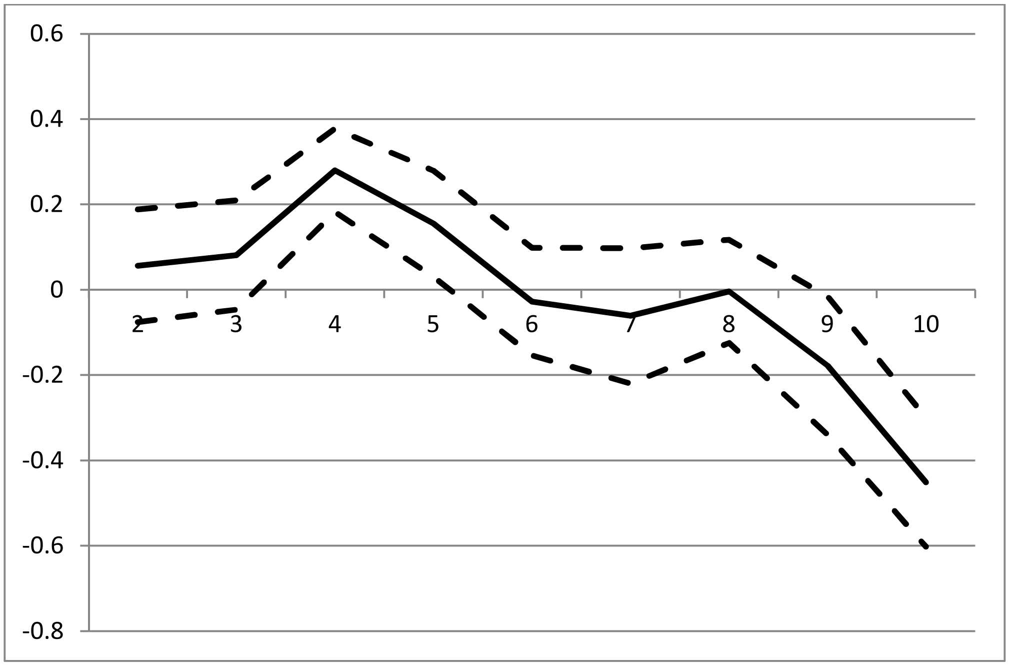

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Table 1: Summary Statistics

	# Obs	Overall Mean	Mean for 330 people from low-science home countries	Mean for 168 people from high-science home countries
Forward citations in year T to scientist's articles published in year t				
Number of citations from home country	39816	0.059	0.032	0.102
Number of citations from USA	39816	0.813	0.503	1.299
Number of citations from home country to global journals	39816	0.058	0.031	0.099
Number of citations from USA to global journals	39816	0.809	0.501	1.292
Number of citations from home country to global journals, excl.agr/environ	30270	0.058	0.027	0.103
Number of citations from USA to global journals, excl.agr/environ	30270	0.884	0.539	1.376
Backward citations in scientist's articles published in year T				
Number of backward citations to home country	4555	0.420	0.182	0.817
Number of backward citations to USA	4555	7.243	5.742	9.745
Number of backward citations to USA excluding collaborations w. advisor	4555	5.469	4.070	7.800
Control variables (mean across observations)				
Fulbright dummy	39816	0.499	0.505	0.488
Scientist from a country <median articles per capita in field	39816	0.610	1.000	0.000
Scientist from a country <median cites per article field	39816	0.725	0.924	0.415
Scientist from a country <75th pctile GDP per capita	39816	0.606	0.954	0.061
ln Number of publications in scientist i's field in home country in citing year	39816	6.462	6.018	7.155
ln Number of publications in scientist i's field in US in citing year	39816	10.082	10.094	10.065
Publications by scientist i in year t	39816	0.831	0.672	1.081
Citations to home-country articles in pre-grad publications	39816	0.744	0.340	1.377
Share of scientist's publications in high-impact journals	39816	0.161	0.134	0.202
Year of citing publication	39816	2005.835	2005.833	2005.837
Year of cited publication	39816	2000.669	2000.750	2000.544
Citation lag	39816	5.165	5.084	5.293
Background control variables (mean across persons)				
Fulbright dummy	498	0.500	0.536	0.429
Female	498	0.237	0.188	0.333
Percentile Rank of Ph.D. program	498	0.320	0.353	0.256
From low-science country of origin	498	0.663	1.000	0.000
Publications while in grad school	498	2.727	2.048	4.060

Table 2: Citations from home country in T to scientist's articles published in year t

	(1)	(2)	(3)	(4)	(5)	(6)
Fulbright	0.0328	0.484**				
	(0.274)	(0.232)				
Fulbright from country >median articles per capita in field			0.118	0.208		
			(0.406)	(0.300)		
Fulbright from country <median articles per capita in field			0.0356	0.936***		
			(0.319)	(0.316)		
Home country <median articles per capita in field			-1.022***	-0.681**		
			(0.271)	(0.274)		
Fulbright from country >median cites per article in field					0.149	
					(0.313)	
Fulbright from country <median cites per article in field					0.751***	
					(0.256)	
Home country <median cites per article in field					-0.585**	
					(0.246)	
Fulbright from country >75th pctile GDPpc						0.264
						(0.288)
Fulbright from country <75th pctile GDPpc						0.776**
						(0.350)
Home country <75th pctile GDPpc						-0.424
						(0.301)
ln Publications in field in home country in citing year		0.431***		0.447***	0.424***	0.435***
		(0.0963)		(0.0916)	(0.0903)	(0.0967)
ln Publications by scientist in cited year		1.188***		1.165***	1.177***	1.182***
		(0.124)		(0.124)	(0.122)	(0.132)
Total citations to home country in pregrad pubs	0.0125***	-0.00143	0.0106***	-0.00202	-0.00221	-0.00180
	(0.00246)	(0.00199)	(0.00231)	(0.00184)	(0.00198)	(0.00190)
1 if female	-0.883***	-0.411*	-1.072***	-0.461**	-0.454*	-0.450*
	(0.261)	(0.233)	(0.262)	(0.232)	(0.237)	(0.236)
ln Rank of PhD program	-0.280**	-0.169*	-0.181*	-0.197**	-0.186**	-0.191**
	(0.109)	(0.0890)	(0.108)	(0.0861)	(0.0867)	(0.0901)

N. obs. = 39,816. Poisson regression coefficients with robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1 All specifications include dummies for field, citing year, year of PhD and citation lag. . Coefficients of these controls available upon request.

Table 3: Citations from USA in year T to scientist’s articles published in year t

	(1)	(2)	(3)	(4)	(5)	(6)
Fulbright	-0.0652	-0.142				
	(0.211)	(0.117)				
Fulbright from country >median articles per capita in field			0.326	-0.0852		
			(0.305)	(0.142)		
Fulbright from country <median articles per capita in field			-0.618***	-0.300*		
			(0.236)	(0.173)		
Home country <median articles per capita in field			-0.432*	-0.298*		
			(0.260)	(0.168)		
Fulbright from country >median cites per article in field					-0.0167	
					(0.153)	
Fulbright from country <median cites per article in field					-0.288	
					(0.176)	
Home country <median cites per article in field					-0.173	
					(0.156)	
Fulbright from country >75th pctile GDPpc						-0.157
						(0.152)
Fulbright from country <75th pctile GDPpc						-0.228
						(0.179)
Home country <75th pctile GDPpc						-0.316*
						(0.167)
ln US Publications in field in citing year		0.622***		0.570***	0.523**	0.567***
		(0.237)		(0.211)	(0.223)	(0.208)
ln Publications by scientist in cited year		1.504***		1.439***	1.466***	1.438***
		(0.107)		(0.0994)	(0.109)	(0.101)
Total citations to home country in pregrad pubs	0.00997***	-0.00428***	0.00829***	-0.00471***	-0.00485***	-0.00464***
	(0.00289)	(0.00146)	(0.00260)	(0.00145)	(0.00154)	(0.00145)
1 if female	-0.727*	-0.158	-0.909**	-0.217	-0.167	-0.189
	(0.379)	(0.227)	(0.359)	(0.217)	(0.220)	(0.213)
ln Rank of PhD program	-0.322**	-0.207***	-0.182	-0.174***	-0.186***	-0.190***
	(0.133)	(0.0568)	(0.111)	(0.0563)	(0.0578)	(0.0575)

N. obs. = 39,816. Poisson regression coefficients with robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1 All specifications include dummies for field, citing year, year of PhD and citation lag (T-t). Coefficients of these controls available upon request.

Table 4: Citations from home country: Robustness

	(1) Adding sector dummies	(2) Controlling for detailed region of origin	(3) Adding country field strength	(4) Only Global Journals	(5) Only Global, Excluding Agri/Enviro	(6) Controlling for journal impact	(7) Controlling for citations from other countries	(8) <90th pctile of cites
Fulbright from country >median articles per capita in field	0.203	0.245	0.165	0.207	0.00229	0.229	0.186	0.0378
	(0.299)	(0.278)	(0.290)	(0.300)	(0.354)	(0.312)	(0.257)	(0.187)
Fulbright from country <median articles per capita in field	0.931***	0.930**	0.882***	0.894***	1.120***	0.952***	1.071***	1.086***
	(0.316)	(0.374)	(0.314)	(0.323)	(0.345)	(0.318)	(0.309)	(0.288)
Home country <median articles per capita in field	-0.649**	-1.087***	-0.434	-0.658**	-0.916***	-0.671**	-0.549**	-0.577**
	(0.280)	(0.301)	(0.273)	(0.277)	(0.325)	(0.278)	(0.267)	(0.292)
ln Publications in field in home country in citing yr	0.436***	0.460***	0.427***	0.435***	0.456***	0.443***	0.478***	0.415***
	(0.0914)	(0.0893)	(0.0890)	(0.0923)	(0.102)	(0.0951)	(0.0873)	(0.0746)
ln Publications by scientist in cited year	1.185***	1.221***	1.149***	1.201***	1.329***	1.157***	0.205	0.987***
	(0.127)	(0.131)	(0.126)	(0.125)	(0.168)	(0.123)	(0.169)	(0.179)
Cites to home-country articles in pregrad pubs	-0.00175	-0.00252	-0.00178	-0.00229	-0.00252	-0.00201	0.000216	0.0729***
	(0.00176)	(0.00179)	(0.00166)	(0.00184)	(0.00250)	(0.00188)	(0.00127)	(0.0227)
Citations per Publication in home country in field in citing year			0.0530***					
			(0.00782)					
Share of pubs in high-impact journals						0.493***		
						(0.167)		
ln Citations from other countries							0.703***	
							(0.0788)	
Sector dummies	Y	Y	N	N	N	N	N	N
Observations	39,816	39,816	39,816	39,816	30,270	39,816	39,816	35,754

Poisson regression coefficients with robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1 All specifications include controls for PhD rank as well as dummies for sector of job (academic/public/private), gender, field, citing year, year of PhD and citation lag (T-t). Coefficients of these controls available upon request.

Table 5: Backwards citations to home country in scientist's articles published in year T

	(1)	(2)	(3)	(4)
Fulbright	1.064***			
	(0.242)			
Fulbright from country >median articles per capita in field		0.828***		
		(0.295)		
Fulbright from country <median articles per capita in field		1.348***		
		(0.370)		
Home country <median articles per capita in field		-0.867**		
		(0.352)		
Fulbright from country >median cites per article in field			0.715**	
			(0.316)	
Fulbright from country <median cites per article in field			1.213***	
			(0.297)	
Home country <median cites per article in field			-0.974***	
			(0.322)	
Fulbright from country >75th pctile GDPpc				0.846***
				(0.311)
Fulbright from country <75th pctile GDPpc				1.293***
				(0.378)
Home country <75th pctile GDPpc				-0.535
				(0.363)
ln Publications in field in home country in citing year	0.379***	0.314***	0.303***	0.344***
	(0.0805)	(0.0828)	(0.0779)	(0.0821)
ln Publications by scientist in citing year	1.022***	0.980***	0.986***	1.009***
	(0.154)	(0.142)	(0.139)	(0.149)
Cites to home-country articles in pregrad pubs	0.00615***	0.00552***	0.00446**	0.00570***
	(0.00180)	(0.00182)	(0.00187)	(0.00183)

N. obs. = 4555. Poisson regression coefficients with robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1 All specifications include controls for PhD rank as well as dummies for gender, field, citing year, and year of PhD.. Coefficients of these controls available upon request.

Table 6: Backwards citations to USA in scientist's articles published in year T

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Excluding pubs with advisor			
Fulbright	-0.0436				-0.0575			
	(0.0602)				(0.0705)			
Fulbright from country >median articles per capita in field		-0.0555				-0.0619		
		(0.0850)				(0.0963)		
Fulbright from country <median articles per capita in field		-0.0383				-0.0729		
		(0.0871)				(0.106)		
Home country <median articles per capita in field		-0.115				-0.125		
		(0.0973)				(0.107)		
Fulbright from country >median cites per article in field			0.0252				0.0198	
			(0.0867)				(0.0973)	
Fulbright from country <median cites per article in field			-0.102				-0.144	
			(0.0739)				(0.0912)	
Home country <median cites per article in field			-0.0287				-0.0471	
			(0.0799)				(0.0904)	
Fulbright from country >75th pctile GDPpc				-0.117				-0.137
				(0.0940)				(0.109)
Fulbright from country <75th pctile GDPpc				0.0189				0.0177
				(0.0880)				(0.109)
Home country <75th pctile GDPpc				-0.104				-0.100
				(0.0946)				(0.105)
ln Publications in field in US in citing year	-0.0658	-0.0676	-0.0692	-0.0666	-0.113	-0.110	-0.112	-0.114
	(0.0805)	(0.0753)	(0.0757)	(0.0795)	(0.0964)	(0.0894)	(0.0889)	(0.0965)
ln Publications by scientist in citing year	1.269***	1.257***	1.263***	1.268***	1.442***	1.430***	1.436***	1.444***
	(0.0587)	(0.0592)	(0.0584)	(0.0597)	(0.0568)	(0.0574)	(0.0568)	(0.0587)
Cites to home-country articles in pregrad pubs	-0.00385***	-0.00407***	-0.00402***	-0.00405***	-0.00493***	-0.00518***	-0.00522***	-0.00511***
	(0.000655)	(0.000664)	(0.000669)	(0.000660)	(0.000723)	(0.000738)	(0.000729)	(0.000739)

N. Obs. = 4,555. Poisson regression coefficients with robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1 All specifications include controls for PhD rank as well as dummies for gender, field, citing year, and year of PhD. Coefficients of these controls available upon request.

Table 7: Effects of Fulbright Status on Location (Linear Probability Models)

	Located in Home		Located in Third		Located Outside US		Located in Home		Located in Third		Located Outside US	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Fulbright	0.329***		0.0608**		0.389***		0.315***		0.0702***		0.385***	
	(0.0378)		(0.0259)		(0.0363)		(0.0379)		(0.0246)		(0.0360)	
Fulbright from country >median articles per capita in field		0.234***		0.137***		0.371***		0.183***		0.0942*		0.277***
		(0.0511)		(0.0411)		(0.0470)		(0.0593)		(0.0484)		(0.0576)
Fulbright from country <median articles per capita in field		0.383***		0.0171		0.400***		0.395***		0.0556**		0.451***
		(0.0412)		(0.0264)		(0.0392)		(0.0452)		(0.0255)		(0.0438)
Home country <median articles per capita in field							0.0752*	-0.0227	-0.0711**	-0.0533	0.00414	-0.0760
							(0.0397)	(0.0521)	(0.0276)	(0.0366)	(0.0392)	(0.0567)
ln Publications in home country in field							0.0115	0.0116	-0.000416	-0.000448	0.0110	0.0112
							(0.0113)	(0.0113)	(0.00784)	(0.00783)	(0.0108)	(0.0108)
Citations per publication in home country in field							0.000275	0.000293	0.000524	0.000520	0.000798	0.000814
							(0.00239)	(0.00235)	(0.00184)	(0.00184)	(0.00233)	(0.00230)
ln Publications by scientist							-0.0275	-0.0265	-0.0611***	-0.0613***	-0.0886***	-0.0878***
							(0.0312)	(0.0328)	(0.0156)	(0.0158)	(0.0303)	(0.0312)
1 if female							0.00296	0.000616	0.0124	0.0129	0.0154	0.0135
							(0.0472)	(0.0468)	(0.0331)	(0.0331)	(0.0449)	(0.0445)
ln Rank of PhD program							-0.00217	-0.00940	-0.0278**	-0.0265**	-0.0300*	-0.0359**
							(0.0175)	(0.0174)	(0.0127)	(0.0127)	(0.0164)	(0.0164)
Constant	0.258***	0.258***	0.0836***	0.0836***	0.342***	0.342***	-0.368**	-0.368**	0.00499	0.00499	-0.363**	-0.363**
	(0.0268)	(0.0268)	(0.0157)	(0.0157)	(0.0289)	(0.0289)	(0.167)	(0.167)	(0.117)	(0.116)	(0.149)	(0.149)
Includes field, year, PhD year dummies	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y
R-squared	0.111	0.121	0.009	0.026	0.152	0.153	0.195	0.205	0.073	0.074	0.242	0.249

N. Obs. = 4,817 including years through 2008. Robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1 . Coefficients of these controls available upon request.

Table 9: Two-stage Least Squares Estimates of Effects of Location on Citations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Fwd cites from home		Fwd cites from US		Backward cites to home		Backward cites to US	
Located in home country >median articles per capita in field	0.0766		2.613		1.369		5.787	
	(0.171)		(2.355)		(2.349)		(8.169)	
Located in home country <median articles per capita in field	0.0587**		-0.125		0.612**		-1.548	
	(0.0291)		(0.344)		(0.251)		(1.741)	
Located in region of home country >median articles per capita in field		0.0535		1.806		0.944		3.914
		(0.119)		(1.570)		(1.621)		(5.497)
Located in region of home country <median articles per capita in field		0.0522**		-0.217		0.535**		-1.644
		(0.0263)		(0.301)		(0.228)		(1.590)
Home country <median articles per capita in field	-0.0139	-0.0164	0.827	0.771	-0.0975	-0.136	2.578	2.463
	(0.0612)	(0.0576)	(0.866)	(0.780)	(0.855)	(0.811)	(3.101)	(2.876)
ln Publications in field in home country in citing year	0.00933***	0.00920***			0.00721	0.00692		
	(0.00234)	(0.00236)			(0.0183)	(0.0183)		
ln Publications in field in US in citing year			0.674*	0.774*			0.401	0.582
			(0.381)	(0.411)			(1.025)	(1.105)
Observations	37,822				4,817			

Robust standard errors, clustered by scientist, in parentheses. *** p<0.01, ** p<0.05, * p<0.1 All specifications include log(publications by scientist), pregrad citations to home country, female, program rank dummies for field, year, and year of PhD.. Coefficients of these controls available upon request.