HOW IMPORTANT IS U.S. LOCATION FOR RESEARCH IN SCIENCE?

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Abstract—This paper asks whether being located outside the United States lowers research productivity in a data set of foreign-born, U.S.-educated scientists. Instrumenting location with visa status that requires return to home countries, we find a large negative relationship between non-U.S. location and research output for countries with low income per capita but none for countries with high income per capita. This suggests that a scientist exogenously located in a country at the top of the income distribution can expect to be as productive in research as he or she would be in the United States.

I. Introduction

THE United States produces more doctorates in STEM (science, technology, engineering, and math)[1] than any other country, is home to a disproportionate share of top scientists (NSF, 2010; Zucker & Darby, 2007) and has many of the most highly rated universities in the world.[2] However, the share of STEM doctoral degrees produced outside the United States has grown in recent years (NSF, 2010), and some countries have increased efforts to attract star scientists.[3] In light of the increasing globalization of science, as well as recent declines in public funding for R&D in the United States, many observers have questioned whether U.S. dominance in science and engineering can be expected to continue (Wadhwa et al., 2007; American Association for the Advancement of Science, 2014). The answer is likely to hinge on whether the U.S. research environment offers inherent advantages to scientists whose productivity would fall if they located elsewhere, or instead whether the United States has merely succeeded in attracting a large number of exceptional scientists who would be productive in any location. Geographic proximity to a high concentration of top scientists that creates large knowledge spillovers, top journals and scientific conferences headquartered in the United States, extensive financial resources devoted to R&D, and a U.S. culture of academic competitiveness may all contribute to a special advantage in science for the United States. These advantages may no longer be determinative, however, because of advances in communication technology and increased investment of other countries in science. As a result, other countries may be able to woo scientists to relocate and the United States could lose its edge in science and engineering research and potentially other types of innovation (Furman, Porter, & Stern, 2002).

This paper directly addresses the question of whether U.S.-based scientists are more productive than those located elsewhere. Specifically, we compare U.S.-educated, foreign-born scientists who stayed in the United States post-Ph.D. to those who went abroad post-Ph.D., in terms of their research output (measured by the number and prestige of publications, first and last authorship), and diffusion and impacts on science (measured by the number of citations to their articles—*forward citations*).

A first look at the research records of a sample of 498 foreign-born scientists who received Ph.D.s from U.S. universities between 1991 and 2005 (table 1) clearly indicates that compared to those located outside the United States, the U.S.-located scientists produce more publications, and more publications in high-impact journals, each year, with the difference starkest between the United States and lower-income countries but still large for higher-income ones. Later tables also show that these U.S.-located scientists' articles also receive significantly more citations.

However, comparisons of scientists inside the United States with those outside are plagued by unobserved heterogeneity among scientists and endogeneity of location choices. For instance, better scientists may be more likely to receive U.S. job offers, desire to remain within the U.S. research community, or face a wide wage differential between locating in the United States versus abroad. Therefore, a naıve comparison of the publications of scientists in different locations would not isolate the impact of location on productivity as distinct from unobserved individual productivity and preferences.

In this paper, we address this problem by constructing a new data set carefully crafted to isolate the impact of U.S. location by exploiting exogenous variation in post-Ph.D. location induced by visa status. The research productivity of 249 foreign-born Ph.D. recipients who came to the United States through the Foreign Fulbright Fellowship program and legally must leave the United States on the completion of their studies is compared to that of a control sample of 249 foreign-born Ph.D. recipients who received their Ph.D.s in the same university, field, time period (and, if possible, the same advisor) but had no visa requirements to leave the United States. Our data are unique in being the only data set of which we are aware that tracks the career

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[1] STEM excludes social sciences.

[2] A Chinese ranking of the world's top universities places the United States as having fifteen and seventeen of the top twenty universities in the world in natural sciences/math and engineering/computer science respectively. (Shanghai Jiao Tong University, 2008). The ranking is based on Nobel laureates and Fields medals prize winners, citations, and publications. We thank Bound, Turner, and Walsh (2000) for identifying this source.

[3] For instance, the Canada Research Chairs program and the Australian Research Council's Federation Fellowships offer incentives to attract researchers to these countries.

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Table 1.—Research Output by Author's Current Location

	Full Sample	In United States, Europe, Asia, Canada, Israel, or Oceania	In United States, Latin America, Africa, or Middle East
Total publication count			
In United States	1.113	1.113	1.113
Abroad	0.725	0.876	0.541
Total	0.907	1.022	0.920
Abroad minus in United States	−0.387	−0.236	−0.571
% difference	−35%	−21%	−51%
Publications in high-impact journals			
In United States	0.509	0.509	0.509
Abroad	0.284	0.345	0.211
Total	0.389	0.446	0.408
Abroad minus in United States	−0.224	−0.164	−0.298
% difference	−44%	−32%	−59%
Observations	4,339	3,301	3,071

progression of individual U.S.-trained Ph.D. scientists, whether they leave the United States or not.[4]

Although we constructed our Fulbright and control samples to be very similar in ability and background, because there may remain differences in inherent research potential between the two groups, we also control for additional background factors, including the income per capita of the country of origin and the pre-Ph.D. publication record. In addition, we show that the distribution of characteristics of individuals in our sample is comparable to the distribution of characteristics in the population of U.S. STEM Ph.D.s of foreign origin; we investigate whether our results change under different hypotheses about bias; we explore alternative matching methods; and we perform a battery of robustness tests (all described in section IV).

To summarize our results, we find that, on average, being outside the United States leads to fewer total, last-authored, and high-impact publications and to fewer citations to high-impact publications. Further, we find that the negative impact of being outside the United States is present and large for those in countries with low levels of GDP per capita but is eliminated for rich countries.

These findings have implications about the global dispersion of research during the coming decades, and particularly whether the United States is likely to retain its current research edge if today's trends continue. In the paper's conclusion, we discuss possible implications and policies that might alter the future path of geographical dispersion of research. Before proceeding to a description of our data, our empirical results, and discussion of the implications of these results, we first address in the following section why U.S. location may directly affect research productivity.

[4] One can obtain information on foreign-born scientists who remain in the United States from the NSF's SESTAT database. Also, Michael G. Finn's (2007, 2010) research provides valuable information on the stay rates of Ph.D.s of foreign origin.

II. Why U.S. Location May Be Important

Why might the United States be a location that engenders greater productivity in scientific research than other locations? First, geographic proximity to other scientists is thought to enhance knowledge diffusion and collaboration. In geographic areas within the United States with greater stocks of knowledge (as measured by past articles, patent applications of scientists working there, the presence of star scientists, or highly ranked academic institutions), there are more new publications, patents, and innovations by both private companies and academics. However, the research on proximity's advantages has struggled to establish this as the impact of location working through geographic knowledge spillovers from nearby scientists rather than mere correlation. The existence of spillovers is suggested by the increased tendency of researchers within the same geographical area to collaborate across institutions and sectors and to cite each other's articles and patents, the tendency of new firms to locate near universities active in that field, and the impact of exogenous changes in universities' R&D funding on geographically close companies.[5] The causal impact of top scientists in prestigious departments on new assistant professors has been isolated by instrumenting prestige with demand and supply factors affecting the academic market at the time of the initial placements (Oyer, 2006; Stephan & Levin, 1992).

Given evidence that geographic closeness to excellent universities and scientists spills over to others' research productivity, the high concentration of top scientists in the United States gives all scientists located within the country an advantage to the extent that these knowledge spillovers are more likely to occur within a country than between countries. Moreover, for U.S.-educated scientists, geographic closeness is likely to foster increased collaboration with Ph.D. advisors and fellow students. Consequently, it seems likely that foreign-born recipients of U.S. doctorates who return to home countries will be less productive than those who remain in the United States. Of course, the same reasoning applies to scientists living far from universities and research centers but within the United States. Nevertheless, distances within the United States are small, on average, compared to the thousands of miles of water and land that separate the United States from all but its few nearest neighbors.

Geographic propinquity is not the only avenue through which scientists can benefit from U.S. location. Well-funded American universities and research institutes can also devote considerable financial resources to increasingly expensive research laboratories and equipment. Many top journals are located in the United States and have mainly American editors and reviewers. Additionally, scientists

[5] See Agrawal, Cockburn, and McHale (2006); Audretsch and Feldman (1996); Audretsch, Lehmann, and Warning (2005); Jaffe (1989); Jaffe, Trajtenberg, and Henderson (1993); Zucker, Darby, and Brewer (1998); Zucker and Darby (2006); and Zucker et al. (2007). However, Orlando (2004) and Thompson and Fox-Kean (2005) have contested the strength of some of this evidence.

located in the United States face lower costs of participating in the many well-attended conferences, seminars, and meetings in the country where they can network and present their research.

Culture itself may also be a factor. Many U.S. universities place a high value on successful research, indicated by prestigious publications and grant awards, and consequently U.S. academia is often characterized by a high degree of competitiveness. Common institutional structures within U.S. academia and research centers make collaboration within the United States easier. Finally, there may be a wider range of jobs in basic scientific research available in the United States.

Moreover, initial career advantage tends to lead to later advantage in academia.[6] Consequently, students who leave the United States post-Ph.D. for visa reasons even for just a few years could see their research careers permanently affected.

Several countervailing forces might have mitigated many of the advantages enjoyed by U.S. researchers in the second half of the twentieth century and early twenty-first century. Advances in communications technology and reductions in the cost of international travel have reduced geographic barriers to knowledge diffusion and long-distance collaboration in science. Over the past decade particularly, other governments have made the development of stronger research capabilities a national priority at a time when U.S. policies may have deterred some scientific explorations.[7] These countries are expanding and improving their doctoral-level educational capabilities, partially by successfully attracting more star scientists. The U.S. share of STEM Ph.D.s awarded is decreasing, and Freeman (2006) documents that in the previous two decades, the major Asian Ph.D.-producing countries went from graduating fewer than half the number of U.S. STEM Ph.D.s to graduating more; somewhat less dramatically, EU countries went from graduating fewer to more STEM Ph.D.s than the United States. Between 2003 and 2007, countries other than the United States slightly expanded their share of the top 100 universities, although they have not made new inroads into the top 20 (Shanghai Jiao Tong University, 2003, 2007). Finally, private sector STEM jobs abroad have also become more widely available as multinationals increase their non-U.S. employment of research scientists and U.S. companies off-shore some high-level STEM jobs to foreign-owned companies.[8]

These factors might be the cause of the increasing collaboration and citations observed recently across state and international borders and decreasing impacts of being in a top university on research productivity.[9] They may also account for the increasing propensity of U.S.-trained highly skilled immigrants (including top scientists) to return to their home countries, dubbed by Annalee Saxenian as a "brain circulation" replacing "brain drain,"[10] and for increasing effects of R&D spending across international borders.[11] Below, we investigate whether these trends have indeed erased any productivity advantage for scientists working within the United States.

III. Empirical Approach and Data Set

A. *The Foreign Fulbright Program as an Instrument*

As noted earlier, comparisons of U.S. and foreign scientists' research output will inevitably be plagued by endogeneity, since scientists' locations are likely to be influenced by unobserved characteristics correlated with productivity. Specifically, the most productive foreign-born U.S.-educated scientists may be the most likely to stay in the United States. The strategy we use to identify the separate impact of location on productivity is to identify pairs of foreign-born U.S. STEM Ph.D. recipients from the same department in the same university graduating during the same period (and, whenever possible, with the same advisor and from the same world region before entering their Ph.D. program)—one of whom is a Fulbright fellow with a J-1 student visa required by law to leave the United States for at least two years after finishing his or her doctorate and one of whom faced no such restrictions.

For Fulbright status to be a useful instrument, we must first establish that far more Fulbright fellowship recipients actually do leave the United States than do other foreigners studying in the United States. The requirement to leave the country after the completion of studies is quite stringent. It is possible to apply for a waiver of the foreign residency requirement if a student falls into one of several very restrictive and quite rare categories.[12] Also, Fulbright reci-

[6] See Stephan (1996) and Oyer (2006).

[7] For example, the number of scientific researchers in China tripled between 1995 and 2010, and in South Korea it doubled (MIT Committee to Evaluate the Innovation Delicit, 2015). While Asian growth in science is relevant for the interpretation of our findings, only a small share of observations in our sample (17.7%) are scientists from Asian countries of origin for reasons we will explain.

[8] See Freeman (2006) and Kim, Morse, and Zingales (2006).

[9] See Adams et al. (2005), Agrawal, Kapur and McHale (2007), Kerr (2008), Kim et al. (2006), and Singh (2005).

[10] See Saxenian (2002), Zucker and Darby (2006).

[11] Kerr (2008).

[12] One route is for students to ask their country of origin to file a "no-objection" statement, although this approach is almost never considered grounds for waiving the foreign residency for Fulbrights (conversation with Boston University International Students and Scholars Office, January 2008). Waivers may also be obtained if an "Interested Government Agency" files a request on behalf of the student, stating that departure of the student will be detrimental to its interest and that of the public. Our conversations with experts suggest that these waivers are obtained only in rare circumstances. Medical doctors may obtain a waiver if they agree to practice in a region of the United States with a shortage of health care professionals. Waivers can be given if "an exchange visitor believes that he or she will be persecuted based on his/her race, religion, or political opinion if he/she were to return to his/her home country." Finally, applications for waivers may be filed on the basis of "exceptional hardship to a United States citizen (or legal permanent resident) spouse or child of an exchange visitor." The State Department warns, "Please note that mere separation from family is not considered to be sufficient to establish exceptional hardship" (http://travel.state.gov/visa/temp/info/info_1288.html). Economists can remain in the United States if they become part of international organizations like the World Bank, an avenue not available for most natural scientists.

pients may delay their departure for two years of a postdoc or for up to three years of occupational or practical training (OPT) on-the-job immediately following the completion of their studies. Thus, in principle, a Foreign fulbright recipient could remain in the United States for up to five years following the receipt of Ph.D. before having to leave the country. Moreover, the Fulbright-subsidized Ph.D. can apply for a work visa and return to the United States after two years spent in their home country.

The enforcement of these rules is sufficiently stringent that almost all foreign Fulbright Ph.D. recipients leave the United States for some period post-Ph.D. Only 12.8% of our Fulbright sample appear to have remained in the United States continuously, and 24.0% appear never to have been in their home country post-Ph.D. and thus not to have fulfilled their home country residency requirement, although even they could have fulfilled the requirement in short segments that we did not observe.[13] For the other 76.0% of the Fulbright students in our sample, we were able to find evidence that they did spend some time in their home country after receiving their Ph.D., compared to only 32.1% of our control group of U.S.-educated foreign-origin non-Fulbrights.

We observe our sample of 249 Fulbright scholars for a total of 2,164 person-years post-Ph.D., with 72.3% of these years spent outside the United States.[14] These years spent outside the United States are mostly spent in the home country: 57.7% of the observations of Fulbrights are in their home countries, and 14.6% of observations of Fulbrights are located outside the United States but in a country that is not their home country. In contrast, the 249 controls spent only 34.1% of their 2,175 observed person-years outside the United States. Of these observations on controls, 25.8% are in their home countries and 8.3% in non-U.S. locations that are not their home countries. This U.S. stay rate of approximately 66% for control students is nearly identical to the average stay rate estimated in a much larger sample by Finn (2007), who found that 67% of foreign students who received their doctorate in 1998 (close to the average Ph.D. year in our sample) were observed in the United States in 2003. A large difference between Fulbrights and controls in their tendency to be outside the United States exists for each region of origin. (Details are given in figure A4 of the online appendix accompanying this paper.[15]) In sum, the Fulbright instrument is strongly correlated with the endogenous variable foreign location.

In order for Fulbright status to be a legitimate instrument, we must also establish that our Fulbright sample is similar to our control group with respect to potential research productivity and proclivity at graduation. Our matching of each Fulbright with a control was done in order to create two groups with similar potential. In order to convince readers that we have done so, we discuss the construction of our control sample in some depth here. Additional details on sample construction are available in the online appendix.

For each Fulbright-funded Ph.D., 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-Ph.D. location restrictions and who graduated from the same program in the same year and, whenever such a student existed, with the same advisor.[16] Since students who receive substantial funding from their home country's government often are required to return for some period, we excluded the student as a control if we found any evidence of foreign governmental funding.

When several potential control students were identified for a single Fulbright fellow, we chose the student who came from the same region or, more generally, from countries similar (particularly in GDP per capita) to the countries represented in the Fulbright sample. However, the distribution of students across countries in the treatment and control groups, while similar, is not identical (as shown in online appendix table A5.) There are several reasons for this. First, the distribution of Fulbrights across countries is affected by past and current political factors. Second, because many students from certain countries receive government funding, we were less likely to select controls from those countries.[17]

We then searched for the Fulbrights' and controls' locations since their Ph.D. receipt on Google, Google Scholar, LinkedIn, or Web of Science, the combination of which allowed us to find both academics and nonacademics.[18] Online appendix figure A3 lists the online sources of information on the locations of Fulbrights and controls and indicates that in general, their distribution across source types

[13] The two-year residency requirement need not even be 730 consecutive days, but could be a combination of summers or semester-long visits abroad while spending the rest of the time in a U.S. postdoc or in OPT. This is discussed in greater detail in Kahn and MacGarvie (2012).

[14] Our original sample as described in Kahn and MacGarvie (2012) 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 who had previously been excluded due to lack of data.

[15] Appendix materials are available at http://people.bu.edu/skahn/.

[16] 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 three years before or after the Fulbright. If no students met the latter criterion, we chose a student graduating in the same year in the same major field but with a different advisor.

[17] There are considerably more Fulbrights from Mexico, Portugal, and South American countries and more controls from China, Germany, Italy, and Turkey. (A complete listing is available in the online appendix.) There are no Fulbrights from China or India in our sample, 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. The reason that there are many Fulbrights from Mexico but no controls is that most of those without Fulbright fellowships are subsidized by their governments. Note that for countries with a large number of Fulbrights, it is preferable *not* to have controls from the same country since it becomes more likely that those who did not receive Fulbrights were of lower quality.

[18] Many academics had CV's posted on the web, which included their location and their previous locations. Nonacademics were more likely to be found on LinkedIn, conference or meeting programs, alumni associations, local news articles, or civic or religious organizations' websites. One person was even located through a DUI arrest. We made sure that the person we located had more than just name in common with the student we knew (e.g., the Ph.D. location or a previous employer might be mentioned). Note that although we had many people's CVs, for consistency we did not base our publication counts on them but used Web of Science instead.

is quite similar. If people were found in the same location and at the same institution several years apart, we assumed that they had been at that location continuously. If we could not find or interpolate the location, we dropped the person-year. Using this method, we dropped fewer than 5% of the person-years due to missing location. Finally, if, in our search for locations or publications, we found that we could not disambiguate a person's publications from others with the same name and field, we dropped the pair.

In sum, the match between treated (i.e., Fulbright) and control students was made with the goal of choosing controls as similar as possible along the characteristics relevant to our study. The criteria we used for matching were based on our priors about the characteristics that are most relevant for future research output (institution, field, year of graduation, and, where possible, advisor and region of origin). Statistics on the closeness of the matches are in the online appendix.

Despite these efforts to ensure that the Fulbrights and controls are as similar as possible along relevant dimensions besides visa status, there still may be concerns that they are inherently different or that the method used to locate them biases whom we find. Section IVB discusses these possibilities in detail.

B. *Estimation Model*

The basic estimating equations in this paper are

$$Y_{it} = \alpha + \beta LAGFORLOC_{it} + \gamma X_{it} + \varepsilon_{it}, \quad (1)$$

$$LAGFORLOC_{it} = \varphi + \xi FULBRIGHT_i + \psi X_{it} + \eta_{it}, \quad (2)$$

where Y is one of nine measures of research output/diffusion, *LAGFORLOC* is whether the individual was in a non-U.S. location in the previous year, and X is a vector of exogenous control variables. Each observation is a person-year starting from the year after Ph.D. receipt and continuing through 2007. Approximately half of the people in our sample are Fulbright fellows in STEM Ph.D. programs listed in the 1993–1996 annual volumes of *Foreign Fulbright Fellows: Directory of Students*.[19] We included all Fulbright fellows in these volumes who received Ph.D.s in STEM whose location could be reliably identified during the post-Ph.D. period and who had at least one matchable control as described in the previous section.

The key right-hand-side variable is a dummy variable for whether the researcher was located in the United States the previous year. We have lagged this variable one year to reflect the lag in science between when research is performed and when it is published.[20]

[19] The first year these lists were published was 1993; they included all foreign Fulbrights enrolled in U.S. graduate programs in that year. Later cohorts would not have had sufficient post-Ph.D. careers.

[20] We also tried a two-year lag with qualitatively similar results, but with larger standard errors because the number of observations were restricted. When more than one lag was included in a single equation, the separate coefficients were typically insignificant because FORLOC is highly serially correlated for each person.

The data set includes only years for which the lagged foreign location of the scientist is known, starting from the year after their Ph.D. graduation year through 2007. This leaves us with 4,339 observations.

C. *Measuring Research Output*

The dependent variables we model were taken from information on the Fulbright and control Ph.D.s' publication histories from ISI's Web of Science for refereed publications.[21] From the Web of Science, we obtained information for the following publication-related variables:

- *Publication counts*. The number of articles each year on which the scientist is a contributing author. This may be a noisy measure of research output when articles have many authors.
- *First-authored publication counts*. The number of articles each year on which the scientist is the first author. In science, the first author is the major contributor to the research.
- *Last-authored publication counts*. The number of articles each year on which the scientist is the last author. In science, typically the last author is the person running the lab, who is often the principal investigator (PI) on the research grant funding the research. This variable is an indicator of the author's ability to secure research funding.
- *Publications in high-impact journals*. The number of each year's publications in the top 50% journals in that field as ranked by ISI's impact factors (as of 2008). We made this measure field-specific because different fields have very different conventions about citations.[22]
- *Forward citation counts*. The total number of citations received as of 2008 by articles published each year, which proxy a publication's impact on scholarship. We model citations to total, first-authored, and last-authored publications and to publications in high-impact journals.[23]

Table 2 displays the publication and citation variables categorized by both present residence (United States or not) and by Fulbright status. The data by present location confirm our expectations: Ph.D. scientists in the United States

[21] Thus, we exclude corrections and conference proceedings. Authors were matched to publications using such information as post-Ph.D. locations, authors' middle names, fields of research, and coauthors on other work.

[22] The list of high-impact journals is available on request.

[23] Due to the extreme skewness of their distributions, publication and citation counts are winsorized at the 99th percentile. For instance, the maximum citation count was 3,451 citations, and we truncate this variable at 307. The authors with the highest counts of publications and citations were mostly part of large collaborative labs with many authors. Even for these people, the number of first- and last-authored publications were measures of their specific contributions and were therefore not winsorized. Results obtained using raw publication and citation counts were generally qualitatively similar to the ones we report here.

Table 2.—Publications and Forward Citations by Post-Ph.D. Location and Fulbright Status

Variable	Observations	Mean	SD	Max	Observations	Mean	SD	Maximum
	Scientists Located in United States				Scientists Located outside United States			
Total Publications Count	2,033	1.113	1.590	6	2,306	0.725	1.268	6
Total Forward Citations Count	2,033	30.646	60.075	233	2,306	14.867	40.449	233
First-Authored Publications	2,033	0.471	0.880	8	2,306	0.325	0.781	12
First-Authored Forward Citations	2,033	9.123	21.392	86	2,306	5.172	15.777	86
Last-Authored Publications	2,033	0.308	1.020	21	2,306	0.239	0.751	10
Last-Authored Forward Citations	2,033	3.593	11.034	47	2,306	2.526	8.822	47
High-Impact Publications	2,033	0.509	0.991	4	2,306	0.284	0.726	4
Forward Citations to High-Impact Publications	2,033	16.962	40.209	156	2,306	7.898	27.036	156
Relative Rank of Ph.D. Program	2,033	0.324	0.254	0.95	2,306	0.300	0.244	0.943
Year	2,033	2002.479	3.104	2007	2,306	2002.732	3.136	2007
Year of Ph.D.	2,033	1997.641	2.293	2005	2,306	1996.790	2.293	2005
Female Dummy	2,033	0.194	0.395	1	2,306	0.228	0.420	1
ln(Home country GDP per capita)	2,033	8.589	1.141	10.319	2,306	8.891	0.890	10.309
First-Authored Pregraduation Publications	2,033	1.656	1.984	15	2,306	1.285	1.822	15
First- or Last-Authored High-Impact Pregraduation Publications	2,033	0.620	1.160	9	2,306	0.573	1.221	9
	Control Scientists				Fulbright Scientists			
Total Publications Count	2,175	1.008	1.504	6	2,164	0.805	1.366	8
Total Forward Citations Count	2,175	25.072	53.797	233	2,164	19.434	48.306	233
First-Authored Publications	2,175	0.420	0.825	8	2,164	0.367	0.838	12
First-Authored Forward Citations	2,175	7.258	18.818	86	2,164	6.787	18.625	86
Last-Authored Publications	2,175	0.313	1.015	21	2,164	0.230	0.736	10
Last-Authored Forward Citations	2,175	3.367	10.441	47	2,164	2.683	9.385	47
High-Impact Publications	2,175	0.454	0.924	4	2,164	0.325	0.801	4
Forward Citations to High-Impact Publications	2,175	14.087	36.106	156	2,164	10.192	31.952	156
Relative Rank of Ph.D. Program	2,175	0.309	0.254	0.958	2,164	0.314	0.244	0.943
Year	2,175	2002.592	3.135	2007	2,164	2002.636	3.112	2007
Year of Ph.D.	2,175	1997.155	2.390	2005	2,164	1997.222	2.273	2005
Female Dummy	2,175	0.206	0.404	1	2,164	0.219	0.413	1
ln(Home Country GDP per Capita)	2,175	8.604	1.120	10.309	2,164	8.895	0.900	10.319
First-Authored Pregraduation Publications	2,175	1.686	1.916	10	2,164	1.231	1.874	15
First- or Last-Authored High-Impact Pregraduation Publications	2,175	0.673	1.189	8	2,164	0.517	1.191	9

do publish more articles and are more highly cited. The differences are substantial. However, dividing the sample by Fulbright status tells a somewhat different story. Although the control scientists are much more likely to be living in the United States, table 2 shows that differences between controls' and Fulbrights' publications and citations average less than 50% of the U.S./non-U.S. spread.

D. *Control Variables*

As explained above, although the Fulbrights and controls were matched to be observationally identical, we also include control variables to account for any remaining differences that may exist between Fulbrights and controls.[24] The control variables include:

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, Maher, & Flattau, 1995) to control for the quality of Ph.D. training. Lower rank signifies higher quality. Since rank is the same for Fulbright and control, this variable only increases the explanatory power across Fulbrights-control pairs.

Field dummies. Fields differ widely in the number of articles published per year and in citing conventions. We categorize each student by the first field listed in their (*ProQuest*) dissertation record. We divide fields into the seven groups listed in table 3.[25] Since the control and Fulbright were chosen from the same field of study, the distribution across fields of study should be exactly identical. There are small differences, however, since often the fields specified in ProQuest are quite narrowly defined and many dissertations list more than one field. If multiple fields are listed on Proquest, we control for the first field listed. Even students of the same advisor and department may list different first fields.

Dummies for calendar year and year of Ph.D receipt. Both variables are included in all specifications,

[24] Employment sector dummies—government, industry, academia—might pick up one reason that scientists in foreign locations are less productive: the scarcity of good academic jobs. However, sector is endogenous in that the best researchers move to countries with more academic jobs. In additional specifications (not shown), we included these dummies. This made no qualitative differences to our conclusions. We also experimented with including a dummy for students from countries with English as an official language, which also did not change our results.

[25] Because of our small data set, we were unable to converge the instrumented model for most output variables for a more detailed set of field dummies. We experimented with different field groupings, and qualitative results were not affected.

TABLE 3.—DISTRIBUTION OF CONTROLS AND FULBRIGHTS, BY FIRST-LISTED FIELD OF STUDY

	Controls	Fulbrights	Total
Agricultural sciences	27	31	58
Biological and behavioral sciences	51	57	108
Engineering and computer sciences	88	85	173
Earth/air/ocean sciences	21	18	39
Mathematics and statistics	21	22	43
Physical sciences	28	23	51
Environment science	13	13	26
Total	249	249	498

with calendar year divided into five eras (1993–1996, 1997, 1998–1999, 2000–2002, and 2003–2007) based on similar levels of average annual publications and citations.[26] There is a similar but not identical distribution across Ph.D. years between Fulbrights and controls, since the control was the closest available foreign student within three years of the Fulbright's Ph.D. (although the mean and median year of graduation are the same; see online appendix table A4) We also divide Ph.D. year into intervals as follows: pre-1997, 1998–1999, 2000–2002, 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.[27]

GDP per capita of home country five years before Ph.D. receipt. The log of the real GDP per capita of the scientist's country of origin before entering a Ph.D. program may affect the quality of predoctoral training or the average financial resources available for the student's doctoral education. On the other hand, this measure is highly correlated ($\rho = .956$) with the home country's GDP per capita. As a result, when the analysis includes current GDP, we do not include this variable as a control, as explained in the results section 4.[28]

Number of articles, first-authored articles, and first-authored high-impact articles published during graduate school. In some specifications (as noted in the tables), the number of pre graduation publications is included.[29] These variables may measure individual-specific variation in past research productivity to proxy for inherent research potential, although they may be endogenous. We extend the "while-in-doctoral-program" period through the year after completion of the doctorate, because these articles are likely to reflect dissertation research rather than new work performed after graduation. Note that first-authored articles are more prevalent during the Ph.D. year than later. In fact, for the average student with any pregraduate publications, 60% of the articles published during this graduate school time were first authored, probably publications from their thesis work for whom the Ph.D. student was the primary author.

Descriptive statistics on control variables are in table 2.

IV. Empirical Results

A. Estimation and Results

Our principal results are in table 4. We estimate publications and citations using a count-data instrumental variables model similar to Poisson regression developed by Mullahy (1997) and estimated via GMM.[30] Standard errors are clustered by scientist. Angrist (2001) has shown that the Mullahy model gives a consistent estimate of the local average treatment effect (LATE) in a model with a binary instrument, endogenous treatment variable and no covariates. Table 4 presents only the coefficients of lagged foreign location. Coefficients of control variables are as expected. Full estimates are available on request from the authors.

Our main instrument for foreign location is Fulbright status. In panel A of table 4, we present results with a single location variable *LAGFORLOC*, a single instrument Fulbright status, and the standard controls without pre-Ph.D. publications. The *F*-statistic measuring the power of Fulbright status in predicting *LAGFORLOC* is high, 103.44, indicating a strong instrument. First-stage regressions for the instrumented results are included as the appendix table.

The results in panel A of table 4 tell us that foreign location has a negative and significant impact on total publications. We are less certain about the impact of foreign location on total citations, since its coefficient is significant only at the 10% level, with a point estimate equivalent to a 59% difference.[31]

Limiting the analysis to first-authored publications (those in which the scientist had the major role in the research) lowers the coefficients on the impact of foreign location)

[26] Again, we were unable to converge the instrumented model for certain dependent variables (notably last-authored and high-impact publications) with a full set of year and Ph.D. year dummies. We have estimated the uninstrumented Poisson regressions with the full set of year and Ph.D. year dummies and did not find results to differ substantially from the results using the more restricted year and year from Ph.D. variables. This is likely due to the fact that our sample of controls and Fulbrights is approximately evenly balanced in terms of year and field characteristics.

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

[28] Data on countries' real GDP per capita and population are from the Penn World Tables version 7, downloaded from https://pwt.sas.upenn.edu/.

[29] We also experimented with including predoctorate high-impact and last-authored publications, but they never had a significant effect on later research, perhaps because there were so few of them.

[30] Mullahy (1997) has shown that an IV Poisson model with unobserved heterogeneity that enters additively in the exponential mean function will be inconsistent when errors are assumed to be additive. Mullahy proposes a transformation of the model with multiplicative errors that is not subject to this problem. We used Stata's ivpois function to estimate these models, modified to allow for clustered standard errors. Similar results were obtained using a linear 2SLS model.

[31] Percentage effects are calculated from Poisson coefficients (β) as $\exp(\beta) - 1$.

Table 4.—Effect of Being Abroad on Publications and Citations

	(1) Total Publications	(2) First-Authored Publications	(3) Last-Authored Publications	(4) High-Impact Publications	(5) Total (fwd) Citations	(6) Cites to First-Authored Publications	(7) Cites to Last-Authored Publications	(8) Cites to High-Impact Publications
A. Controls for Home Country GDP, No Pregraduation Publications								
LAGFORLOC	−1.085***	−0.714	−1.106**	−1.555**	−0.956*	−0.382	−0.808	−1.258*
	(0.406)	(0.437)	(0.462)	(0.640)	(0.514)	(0.575)	(0.681)	(0.656)
B. Controls for Home Country GDP and for Pregraduation Publications								
LAGFORLOC	−0.706*	−0.383	−0.983*	−1.487**	−0.614	0.111	−0.826	−1.920*
	(0.366)	(0.392)	(0.504)	(0.623)	(0.475)	(0.609)	(0.839)	(0.544)
C. Percentage Impact of Being Abroad by Percentiles of ln(per cap GDP current country), No Controls for Pregraduation Publications								
25th percentile	−0.839***	−0.738***	−0.930***	−0.921***	−0.885***	−0.643***	−0.919***	−0.943***
50th percentile	−0.715***	−0.569***	−0.808***	−0.824***	−0.710***	−0.382	−0.719***	−0.809***
75th percentile	−0.538***	−0.344	−0.548***	−0.655***	−0.367	−0.018	−0.199	−0.468
90th percentile	−0.397	−0.171	−0.272	−0.499*	−0.023	0.271	0.435	−0.059
D. Percentage Impact of Being Abroad by Percentiles of ln(per cap GDP current country), with Controls for Pregraduation Publications								
25th percentile	−0.739***	−0.543**	−0.923***	−0.924***	−0.799***	−0.111	−0.932***	−0.927***
50th percentile	−0.581***	−0.382	−0.790***	−0.816***	−0.587**	−0.076	−0.766***	−0.775***
75th percentile	−0.375*	−0.202	−0.509**	−0.612***	−0.240	0.265	−0.332	−0.420
90th percentile	−0.219	−0.081	−0.213	−0.411	0.066	0.384	0.196	−0.017
E. Subsample from Rich Home Countries, Controls for Home Country GDP, Not Pregraduation Publications								
LAGFORLOC	−0.094	0.396	0.212	0.014	0.289	1.057	0.821	0.185
	(0.550)	(0.701)	(0.923)	(0.714)	(0.587)	(0.720)	(0.962)	(0.765)
F. Subsample from Rich Home Countries, Controls for Home Country GDP and Pregraduation Publications								
LAGFORLOC	0.161	0.480	0.402	0.924	0.776	1.413*	1.066	1.856
	(0.550)	(0.772)	(0.840)	(0.854)	(0.619)	(0.753)	(0.920)	(0.241)
G. Subsample from Poor Home Countries, Controls for Home Country GDP, Not Pregraduation Publications								
LAGFORLOC	−1.453**	−0.633	−1.478*	−2.529***	−1.892**	−0.694	−3.340*	−2.791***
	(0.616)	(0.656)	(0.837)	(0.769)	(0.669)	(0.874)	(2.027)	(0.702)
H. Subsample from Poor Home Countries, Controls for Home Country GDP, and Pregraduation Publications								
LAGFORLOC	−0.819	0.020	−1.635**	−2.255***	−1.287**	−0.173	−5.365*	−2.183***
	(0.450)	(0.485)	(0.828)	(0.711)	(0.535)	(0.713)	(2.221)	(0.656)
I. Controls for Top-Ranked Current Institution, Home Country GDP, and for Pregraduation Publications								
LAGFORLOC	−0.723*	−0.387	−1.041**	−1.555**	−0.630	0.173	−0.995	−0.972**
	(0.378)	(0.419)	(0.528)	(0.655)	(0.493)	(0.698)	(0.874)	(0.570)

Significant at *10%, **5%, ***1%. Robust standard errors clustered by scientist in parentheses. Estimated as Mullahy count-data IV model. Endogenous explanatory variables panels A, B, E–H: lagged foreign location (LAGFORLOC); Instrument: Fulbright dummy. Endogenous explanatory variables panels C and D: LAGFORLOC, LAGFORLOC×ln(lagged)current GDP. Instruments: Fulbright dummy and lagged ln(real home country GDP). Exogenous explanatory variables: scientific field dummies, period dummies, Ph.D. year dummies, gender, ln(rank of Ph.D. institution). In specified regressions, also include ln(real home country GDP per cap five years prior to graduation) and pregraduation total, first, and first high-impact publications.

on both publications and citations and renders them insignificant.

In many scientific fields, last authorship signifies that the person ran the lab and was the PI who obtained the funding. We find that being outside the United States has a significant, large, negative average effect on last-authored publications (−67%). However, citations to these articles are not significantly lower on average.

Finally, *LAGFORLOC* also has a large and significant impact on publications and citations in high-impact journals, at −81% for publications and −80% for citations.

Controlling for pregraduate publications (panel B) lowers point estimates and significance levels of the impact of foreign location) across the board. However, although the gap between the United States and abroad narrows, it is still statistically significant for total publications (p-value = .07), last-authored publications (p-value = .05), high-impact publications (p-value = .02), and citations to high-impact publications (p-value = .03).

Overall, the results from panels A and B suggest negative effects of being abroad on some measures of research output, with fewer when conditioned on publications while in graduate school.

However, the impact of being outside the United States on scientists is likely to be heterogeneous. One factor that may affect the magnitude of any negative impact of being abroad is the wealth of the country in which the scientist is located, measured by its real GDP per capita. We expect that the research output of those who are in less developed countries with fewer resources for research would be most hurt by being outside the United States. However, the GDP of the scientist's foreign location will also be endogenous, with the most research-oriented Ph.D. recipients more likely to get jobs in richer countries with more resources devoted to science.

We differentiate the effect of being outside the United States by GDP per capita in two ways. In panels C and D of table 4, the two endogenous variables related to foreign location are *LAGFORLOC* alone and *LAGFORLOC* interacted with the GDP per capita of the current country (*LAGFORLOC X ln(lagged)GDP)*. The instruments that we use are Fulbright status and the lagged (log of) GDP per capita of the home country. The GDP per capita of the home country captures the differential effect of location for students from countries with different levels of income. Since it is based not on current country but home country, it is clearly predetermined. Note that in this case, we have not controlled for the home country's GDP five-years period to Ph.D. receipt since it is so highly correlated with present (lagged) GDP of one's country of origin. The *F*-statistics on these instruments are 74.06 (*LAGFORLOC*) and 79.38 (*LAGFORLOC* $\times$ *ln(lagged)GDP)*. The first-stage regression results are found in the appendix table, columns 2 and 3. Panels C and D of table 4 present estimates of the impact of being abroad at four points in the distribution of GDP per capita: at the 25th, 50th, 75th, and 90th percentiles, controlling and not controlling for pregraduate publications, respectively.

The income per capita of the country in which the scientist is located does seem to mitigate the effects of being outside the United States, with the point estimates of the impact of being abroad more negative in poorer countries than in richer ones for all research measures. Thus, once we instrument to account for selection bias induced by endogenous differences in foreign locations, there is no statistically significant negative difference between scientists in the richest countries (90th percentile of GDP per capita) and those in the United States on any of the measures of research output. In other words, the negative impact of foreign location is completely absent in countries with higher GDP per capita. In contrast, scientists in countries with low GDP per capita are significantly negatively affected by foreign location. When pregraduate publications are not controlled for, scientists from countries at the 25th percentile of the GDP per capita distribution are significantly negatively affected by foreign location in terms of all publication and citation measures, while those at the 50th percentile of the GDP per capita distribution are significantly negatively affected for all output measures except citations to last-authored articles. After controlling for pregraduate publications, point estimates and significance of the impacts fall somewhat, but most remain significant at both the 25th percentile and 50th GDP percentile, although citations to last-authored articles are not significantly different at any income level.

Panels E through H of table 4 use a different approach to measure separate effects of being in rich versus poor countries. They divide the sample into two groups, the first comprising scientists from richer countries (defined as in the top quartile of countries' real GDP per capita in the year of graduation) and the second comprising the rest of the world.[32] For those from rich countries, the effect of being abroad on every measure of scientific output is actually positive rather than negative, and even significantly so for two measures.[33] In contrast, for scientists originally from poor countries, the impact of being abroad is negative (except for first-authored publications) and significantly so for many measures (with and without pregrad publication controls). Thus, the impact of being outside the United States was significantly negative for both specifications for high-impact publications, total citations, and cites to high-impact publications and only consistently insignificant for first-authored publications and cites to those publications.

Finally, in results not included here, we estimated the main models without instrumenting.[34] We expected uninstrumented coefficients to be more negative than the instrumented ones because we believed that those with a higher propensity to publish are more likely to stay in the United States. We did find the uninstrumented results to be more significant in general than the instrumented ones (e.g., in table 4, panels A and B). However, we found that the instrumented impact of being abroad is often larger (in percentage terms) than the uninstrumented one. In the separate rich/poor regressions comparable to table 4, panels E to H, we found that the effect of being abroad in a rich country is much more negative in the uninstrumented ones, and often significantly so. Thus, selection bias dominated OLS results for those from rich countries: those with a higher propensity to publish are more likely to remain in the United States. However, for those from poorer countries, the instrumented results were uniformly more negative than the uninstrumented ones. One possible explanation is that the instrumented results for those from poorer countries are picking up the local average treatment effects (LATE) for the compliers—the Fulbrights who comply with the foreign residency requirements of their visas and therefore are in their home countries. In contrast, uninstrumented results combine Fulbrights abroad with controls abroad who have voluntarily chosen to return to their home countries (the "always takers" in the language of Angrist, Imbens, & Rubin, 1996), probably because they have more opportunities there or fewer opportunities in the United States.

It is worth noting that not all foreign research institutions are created equal. Heterogeneity across institutions around the world ensures that a top-ranked institution in a high-income foreign country will often be a more fertile environment for research than the median U.S. university. To investigate how the effects of location depend on the quality of the foreign institution, in panel I of table 4, we add a control equal to 1 if the scientist's current institution is the

[32] Note that these analyses are able to include the home country GDP per capita (five years pre-Ph.D.) as a control variable because there is no other GDP variable in the estimation. First-stage results in the appendix table columns 4 and 5.

[33] Cites to first-authored publications and cites to high-impact publications, both controlling for pregraduate publications.

[34] The results are available on request from authors.

highest-ranked institution in the country according to the Quacquarelli Symonds (QS) World University Rankings.[35] These results need to be interpreted carefully because this variable is endogenous. By adding together the coefficient on the foreign location dummy and the coefficient on the top-ranked foreign institution dummy, we find that for scientists working at the foremost institution in their country of residence, the negative effects of foreign location on productivity are substantially diminished. The reduction is largest for high-impact publications: while being abroad reduces high-impact publications by 81.7% on average (column 4, panel A of table 4), being abroad at the top institution in one's country reduces high-impact publications by 61.4%.

To summarize the major results from this section, research output and the dissemination of this output suffer for scientists who leave the United States for low-GDP countries, even after the endogeneity of that location choice is accounted for by instrumenting. The one exception may be first-authored publications and cites to these publications, although even for these, there is some indication of a negative impact of being in the very poorest countries. In contrast, being outside the United States does not seem to impede research or diffusion for researchers located in countries with more wealth and resources. Results controlling for pregraduation publications are likely to be an underestimate of the impact of location, but even these indicate quite negative impacts of being in low-income countries.

B. *Potential Biases*

Perhaps the most serious potential criticism of our instrument is the possibility that Fulbright status is inherently correlated with a researcher's quality, independent of location, implying that the exclusion restriction is violated. A similar potential problem would affect interpretation of the estimates if the method we used to find the Ph.D.s' locations biases us toward finding certain kinds of people in ways that affect Fulbrights and controls differently. We address these concerns next.

Potential biases associated with differential inherent ability. Countries generally have their own committees that award Fulbright Fellowships based on their own selection criteria. We assume that academic excellence is one of these criteria, and this could mean that the typical Fulbright recipient has greater inherent potential for research than the typical randomly selected student from the same department. Alternatively, national Fulbright commissions might avoid funding the most promising students if they are believed to be less likely to spend their careers in their home country, which would result in Fulbrights having less research potential than controls on average. Moreover, many excellent students may not accept Fulbright Fellowships if they have strong preferences to remain in the United States post-Ph.D. or can afford to avoid funding that restricts their futures.

To the extent that U.S. universities can observe the differences among students, the university admissions procedure should ensure that the Fulbrights and non-Fulbrights they admit to any specific department have approximately equivalent abilities. However, future research preferences may not be entirely observable to U.S. university admissions or U.S. departments may lower their standards somewhat for graduate students who are already funded by a fellowship at the time of application. Finally, Fulbright Fellows might not apply to the university best matched to their abilities. In many countries, Fulbright commissions guide fellows towards particular U.S. universities, sometimes influenced by the availability of supplementary fellowship funding from the university or the lower tuition costs of public universities.[36]

In short, there are possible biases leading to Fulbrights' having inherently higher ability and other possible biases leading to Fulbrights' having inherently lower ability. As shown below, if Fulbrights have greater inherent ability than controls, the IV results will be biased against finding a negative effect of foreign location on productivity. If Fulbrights have lesser inherent ability than controls, the IV results will be biased toward finding a negative effect of foreign location on productivity.

Potential biases associated with use of online data sources. It is possible that the online information that we use to identify the locations of individuals in our sample is more readily available for the most productive scientists. This could occur if scientists working in academia both publish more and are more likely to post CVs when compared with scientists working in industry or if the scientists with the most publications are most eager to publicize their accomplishments. Thus, we would have attrition of the least productive scientists from the sample. Let us consider how this could affect our results under different scenarios.

If this tendency toward self-promotion is independent of Fulbright status and location, our data exhibit parallel attrition. In other words, the factors leading to attrition are common in the United States and other countries. This would imply that our results on productivity differentials are informative about a sample of scientists with above-average productivity. However, we would not expect parallel attrition to lead to over- or underestimating the effects of location on the productivity in this sample.

[35] This ranking was downloaded from http://www.topuniversities.com/university-rankings. This ranking was selected because of its comprehensive coverage (it covers 2,000 global universities). Of the foreign-located observations in our sample, 8.9% are at top-ranking institutions according to this measure. Unlike the NRC rankings we use to classify the rank of students' graduate program, these rankings are institution-wide and not program specific. Results are robust to using an alternative university ranking (the 2003 Academic Ranking of World Universities).

[36] Conversation with IIE representative, June 2009.

By contrast, if the probability of attrition from the sample depends on location, bias may be introduced. For example, if people living outside the United States have stronger incentives to self-publicize in order to maintain their connections to U.S. science, we may be more likely to collect data on the full distribution of productivity in foreign countries, while it is only the more productive scientists in the United States who post information about themselves online. This would introduce negative bias in our estimate of the effect of foreign location because our sample of foreign scientists is representative of the population, while our sample of U.S.-based scientists is positively selected.

Alternatively, if online information on individuals living in lower-income countries is less prevalent due to those countries' less-developed Internet infrastructures, we may tend to collect data on only the most productive individuals in those countries.[37] This would lead to positive bias in our estimates of the productivity of those located abroad, particularly in lower-income countries.

Evaluating the extent of bias. Information on the locations of scientists in our sample was obtained from a variety of online sources. The most common was an online CV, with 28.7% of observations on controls' locations and 29.7% of Fulbrights' locations coming from this source. Other common sources are LinkedIn, with 22.3% of control observations and 17.7% of Fulbright observations; faculty websites or web bios, with 14.7% and 17.7% of observations, respectively; and publications, with 14.6% and 13.9% of observations, respectively (Figure A-3 of the online appendix shows the distribution of all sources Fulbrights and controls in more detail.) Moreover, average publications are not different for those academics who post and do not post their CVs or LinkedIn profiles and this is true for those in the United States and abroad (shown in the online appendix, table A-3). Based on this analysis of the sources of location data, we conclude that there is little reason to believe that results are biased by differential availability of online information about Fulbrights and controls.

We can also compare some of our data with random samples of STEM Ph.D.s from other sources to establish whether the U.S.–foreign publication differences that we have calculated for our sample obtained through online methods reflect U.S.–foreign differences among the larger population of doctoral recipients. The NSF's Survey of Doctoral Recipients (SDR) follows a random sample of U.S. doctorate recipients who remain in the United States as their careers unfold, with survey waves typically every two years. Unfortunately, only those who remain in the United States are tracked by the SDR. However, we can compare the foreign Ph.D.s in our sample who remain in the United States to those in the SDR. The 2001 wave of the SDR asked respondents to self-report the number of "published articles in refereed professional journals" over the previous five years. We extracted a subsample of the SDR consisting of temporary residents in STEM with Ph.D.s conferred from 1996 to 2001 to ensure comparability with our sample. We then computed the average and median number of publications per year for each cohort.

We then compared these numbers to the publications in our analysis for those who remain in the United States. Recall that our publication measures are based on refereed publications found on the Web of Science which, while quite comprehensive, is not a complete list of refereed journals. We also compared these two sources to the number of publications in refereed journals self-reported by individuals in our sample for whom we found CVs and who were in the United States continuously between 1996 and 2001. We found that the article counts for the scientists in our sample are similar to the article counts reported by the SDR for each survey wave (see online appendix table A-7). In no survey wave is the difference between our sample's mean publications and the mean publications in the SDR statistically significant. In sum, we conclude that there is no evidence that our data collection methodology has substantially biased the number of publications of those observed living in the United States and particularly did not bias these numbers upward.

There may still be concern that the use of online data induces sample selection bias for scientists located abroad, who in our sample are more likely to be the Fulbrights. We cannot compare publication data in our sample with those of a randomly selected group of foreign scientists with U.S. Ph.D.s because the latter data set is not available (to our knowledge). However, we can compare the basic characteristics of the Fulbrights and controls in our sample with the characteristics of the universe of people receiving U.S. Ph.D.s in STEM, based on the NSF's Survey of Earned Doctorates (SED). The SED is distributed to doctoral recipients at the time of completion of their degrees and contains information about their demographic characteristics, country of origin, and post-graduation employment plans but not about their research productivity. We make this comparison for the Ph.D. years (1996 and 1997) in which SED respondents were asked about their specific sources of funding, including Fulbright fellowships. We identify in these years the STEM Ph.D. recipients of foreign origin who did not have Fulbright funding and those who did have Fulbright funding. We compare the postdegree employment (academic, private, or government) of Fulbrights and controls in our sample in the year after they graduate with the postgraduation employment plans of Fulbrights and non-Fulbright foreigners obtaining U.S. Ph.D.s in the SED. We find that the scientists in our sample are remarkably similar to graduating scientists in general. The details of these results are described in the online data appendix and particularly table A-6.

[37] It is not realistic to expect this source of bias to affect our estimates of the effect of being in a high-income country (e.g., at the 90th percentile of GDP per capita), since Internet availability in these countries is sufficiently similar to that in the United States.

In addition to bias induced by the sources of our productivity data, there may be more general concern that the Fulbright instrument is positively or negatively biased. We have done several things in order to remove or evaluate possible biases due to potential differences in the research potential of Fulbrights and controls. First, we control for explanatory variables likely to be correlated with research ability and proclivity. One such variable is the Ph.D. institution's rank. Since this is identical within the pair, inclusion of this variable serves only to increase the explanatory power across pairs. Second, in most specifications, we control for the GDP per capita of the home country at the beginning of graduate school. This helps to control for variation across home countries in the quality of undergraduate education.

Third, in some specifications, we also include as control variables measures of students' research output while in graduate school, which we believe to be a good proxy for inherent ability. Including these pregraduation publication variables may overcontrol in the sense that at least some of the Fulbright–control differences in pregraduation publications may also be a result of being a Fulbright. For instance, if Fulbrights believe that they will return home to a nonresearch job, they may be less committed to getting their Ph.D. research published. But if Fulbrights are more concerned about having opportunities to leave their home country after two (or more) years of residence, they may feel they need stronger credentials. Poisson regressions of students' pregraduation research output variables on the Fulbright dummy, region of origin, field, and Ph.D. year indicate a 25.8% lower rate of total publications among Fulbrights that is not significant at conventional levels (p-value = .0.064) and an even less significant 14.0% lower rate among Fulbrights for first-authored publications (p-value = .265). We believe the first-authored pregraduation publication count to be a more direct measure of student's future research potential.[38]

Sensitivity of results to violation of the exclusion restriction. As a further guide to the interpretation of our estimates, in this section, we provide some estimates of the potential effects of bias introduced by correlation between the dependent variable and the instrument. Our approach is based on that of Angrist et al. (1996), who examine the implications of a violation of the exclusion restriction in the relationship between civilian mortality and draft status. In the interest of simplicity, we assume a linear (2SLS) model.

Let Y_i represent the research measure for person i (publications, citations), D_i be *LAGFORLOC*, and Z_i be the Fulbright instrument (with both D_i and Z_i being dummies.) The coefficient in the simple OLS regression of Y_i on D_i is

$$\beta_{\text{ols}} = \text{Cov}(Y_i, D_i)/\text{Var}(D_i).$$

The 2SLS equivalent of β_{ols} is:

$$\beta_{2\text{sls}} = \text{Cov}(Y_i, Z_i)/\text{Cov}(D_i, Z_i).$$

The exclusion restriction in our context implies that Fulbrights systematically differ from controls only because they were required to leave the United States post-Ph.D., and therefore without this return requirement, Fulbrights would have had the same outcomes (publications, cites) as non-Fulbrights.

If this exclusion restriction does not hold, the IV estimator will be biased. Suppose that the true model is

$$Y_i = \beta_0 + \beta_1 D_i + Q_i + \varepsilon_i,$$

where Q_i is the unobserved quality of the student. Then the 2SLS estimator will be

$$\begin{aligned}\beta_{2\text{sls}} &= \text{Cov}(\beta_0 + \beta_1 D_i + Q_i + \varepsilon_i, Z_i)/\text{Cov}(D_i, Z_i)\\ &= \beta_1 + \text{Cov}(Q_i, Z_i)/\text{Cov}(D_i, Z_i),\end{aligned}$$

assuming $\text{Cov}(\varepsilon_i, Z_i) = 0$. This says that the IV estimate of the causal effect will be biased by the ratio of the covariance between quality and Fulbright status to the covariance of location and Fulbright status.[39] Assuming

$$\begin{aligned}Q_i &= \gamma_0 + \gamma_1 Z_i + \xi_i,\\ D_i &= \alpha_0 + \alpha_1 Z_i + \nu_i,\end{aligned}$$

then

$$\begin{aligned}\text{Cov}(Q_i, Z_i) &= \gamma_1 \text{Var}(Z_i),\\ \text{Cov}(D_i, Z_i) &= \alpha_1 \text{Var}(Z_i).\end{aligned}$$

Therefore:

$$\beta_{2\text{sls}} = \beta_1 + \gamma_1/\alpha_1,$$

where γ_1 is the additional number of publications from the "quality effect" of being a Fulbright and α_1 is the increase in the probability of being outside the United States from being a Fulbright. Note that even if γ_1 is nonzero—in other words, the exclusion restriction is violated—the amount of bias will be small as long as the instrument is very strong (α_1 is large in absolute value).

[38] When we exclude controls for field, year, and region, the coefficient on Fulbright is significant in the total pregraduation publications regression but insignificant in the regression in which the dependent variable is first-authored pregraduation publications. Results are similar for negative binomial models for first-authored publications, while the result has similar magnitude but greater significance for total publications. When we exclude controls for field, year, and region, the coefficient on Fulbright is significant in the total pregraduation publications regression, but insignificant in the regression in which the dependent variable is first-authored pregraduation publications.

[39] Angrist et al. (1996) compute 2SLS estimates of the impact of veteran status on mortality using draft lottery number as an instrument. The concern in their case is that the exclusion restriction is violated because draft numbers affect mortality through their influence on years of schooling. They use this method to estimate the amount of potential bias.

TABLE 5.—SENSITIVITY ANALYSIS OF 2SLS (LIML) ESTIMATES OF THE EFFECT OF BEING ABROAD BY INCOME LEVEL OF HOST COUNTRY

Percentile	(1) Total Publications	(2) First-Authored Publications	(3) Last-Authored Publications	(4) High-Impact Publications	(5) Total (fwd) Citations	(6) Cites to First-Authored Publications	(7) Cites to Last-Authored Publications	(8) Cites to High-Impact Publications
				Assumption: Zero Bias				
25th percentile	−1.415***	−0.424	−0.859*	−0.783**	−45.566***	−5.559	−7.313**	−27.075***
50th percentile	−0.907***	−0.262	−0.508**	−0.519**	−27.813**	−3.096	−4.168**	−17.117**
75th percentile	−0.478**	−0.126	−0.211	−0.296**	−12.783	−1.010	−1.504	−8.686
90th percentile	−0.239	−0.050	−0.046	−0.172	−4.426	0.150	−0.024	−3.998
				Assumption: Negative Bias of 1 Quartile				
25th percntile	−1.356***	−0.397	−0.842**	−0.758***	−44.092***	−5.074	−7.123**	−26.273**
50th percentile	−0.848**	−0.236	−0.492**	−0.494**	−26.339**	−2.611	−3.977**	−16.314**
75th percentile	−0.419*	−0.099	−0.195	−0.271*	−11.308	−0.525	−1.314	−7.883
90th percentile	−0.180	0.023	−0.030	−0.146	−2.951	1.634	0.167	−3.195
				Assumption: Positive Bias of 1 Quartile				
25th percentile	−1.474***	−0.450*	−0.876***	−0.809***	−47.041***	−6.044	−7.504**	−27.878***
50th percentile	−0.966***	−0.289	−0.525**	−0.545***	−29.288***	−3.280	−4.358**	−17.920**
75th percentile	−0.537**	−0.152	−0.228	−0.321**	−14.258*	−1.495	−1.695	−9.488*
90th percentile	−0.298	−0.076	−0.063	−0.197	−5.900	−0.335	−0.214	−4.801

Significant at *10%, **5%, ***1%. Exogenous explanatory variables: scientific field dummies, period dummies, Ph.D. year dummies, gender, ln(rank of Ph.D. institution). Endogenous explanatory variables: LAGFORLOC, LAGFORLOC X ln (lagged) current GDP. Instruments: Fulbright dummy and ln home country GDP five years yrs prior to graduation.

Let us assume that the quality effect of being a Fulbright means the Fulbright is either over- or underplaced at his Ph.D. institution relative to controls. For example, consider the possibility that Fulbrights are overplaced, that is, they are admitted to programs that would not have admitted them if they were controls, and as a result, Fulbrights from a given institution can be expected to have lower inherent ability than controls from that institution, independent of where they are located after the completion of the Ph.D. program.

To determine the magnitude of the bias this would introduce, suppose that Fulbrights are typically admitted by programs that are either of higher or lower rank than the best program that would admit the Fulbright without the fellowship. By definition, controls are accurately matched with their Ph.D. institutions. Regressing controls' research output on institution rank in percentiles and controlling for the year of Ph.D. and the observation year, we obtain the estimated impact on research output of moving up or down a quartile of rank.[40]

We then perform sensitivity analysis in which we consider the possibility that Fulbrights on average have either higher or lower inherent research potential than controls. We consider two scenarios, and for each scenario, we compute $\beta_1 = \beta_{2sls} - \gamma_1/\alpha_1$.

1. Fulbrights are admitted to programs ranked 25 percentage points higher than the program that would admit them without the fellowship (This would be equivalent to Fulbrights attending Stanford or Harvard instead of Penn State or Texas A&M.)
2. Fulbrights are admitted to programs ranked 25 percentage points lower than the program that would admit them without the fellowship.

In table 5, we present the results of this sensitivity analysis, using the 2SLS estimates of the effect of foreign location at each of the four income levels discussed in the paper.[41] We find that the qualitative results for scientists from countries of different income levels are the same whether assuming a 25% positive or negative bias. People in countries with the lowest income levels who live abroad are negatively affected, and significantly so in both the statistical and economic meaning of the word. People in the richest countries have small and mostly insignificant differences in research output, and point estimates are often positive. Of course, the size of the negative impact is larger if Fulbrights actually were better than their peers and is smaller than if Fulbrights actually were worse, although the differences in magnitudes due to bias are not large.

Our overall conclusion drawn from this sensitivity analysis is that for reasonable amounts of potential bias, either positive or negative, the strength of the instrument dominates the bias. As a result, our results are qualitatively unchanged. We recognize that if Fulbrights and controls are much more dissimilar than assumed here, we would have difficulty interpreting our results, especially for countries at the high end of the income distribution. However, given the steps we have taken to ensure comparability of students within the matched pairs and the control variables we have included to account for student hetero-

[40] Specifically, we calculate the average of the coefficients across all the publication regressions and multiply this number by 0.25 (one quartile) to get the estimated elasticity of moving up or down a quartile in program rank. This elasticity is calculated as 8.8% (an 8.8% reduction in research output associated with a one-quartile reduction in rank).

[41] Not controlling for pregraduation publications.

Table 6.—Effect of Being Abroad on Publications and Citations

	(1) Total Publications	(2) First-Authored Publications	(3) Last-Authored Publications	(4) High-Impact Publications	(5) Total (fwd) Citations	(6) Cites to First-Authored Publications	(7) Cites to Last-Authored Publications	(8) Cites to High-Impact Publications
A. Subsample from Rich Countries, Controls for Home Country GDP, Not Pregraduation Publications								
% of years abroad	0.075	0.626	0.584	−0.138	0.737	1.765**	1.327	0.689
	(0.619)	(0.736)	(0.826)	(0.848)	(0.730)	(0.853)	(0.877)	(1.004)
B. Subsample from Rich Countries, Controls for Home Country GDP and for Pregraduation Publications								
% of years abroad	0.156	0.356	0.394	0.918	0.868	1.414**	1.208	1.728
	(0.585)	(0.678)	(0.718)	(0.844)	(0.671)	(0.701)	(0.802)	(1.093)
C. Subsample from Poor Countries, Controls for Home Country GDP, Not Pregraduation Publications								
% of years abroad	−1.306**	−0.850	−0.739	−2.101***	−1.610**	−0.709	−1.607	−2.286***
	(0.574)	(0.568)	(0.712)	(0.734)	(0.662)	(0.637)	(1.327)	(0.765)
D. Subsample from Poor Countries, Controls for Home Country GDP and for Pregraduation Publications								
% of years abroad	−0.734*	−0.166	−0.916	−1.721***	−1.060*	−0.198	−2.181	−1.650***
	(0.387)	(0.391)	(0.676)	(0.533)	(0.495)	(0.569)	(1.339)	(0.574)
E. Subsample from High Article per Capita Countries, Controls for Home Country GDP, Not Pregraduation Publications								
% of years abroad	1.101	2.864	4.198	1.615	1.905	2.782	3.584	1.639
	(1.209)	(2.528)	(6.999)	(1.566)	(1.544)	(2.052)	(3.680)	(1.774)
F. Subsample from High Article per Capita Countries, Controls for Home Country GDP and for Pregraduation Publications								
% of years abroad	0.854	1.486	2.042	2.731	1.964	2.489**	2.867*	7.018
	(0.922)	(1.296)	(1.525)	(1.883)	(1.196)	(1.145)	(1.515)	(10.34)
G. Subsample from Low Article per Capita Countries, Controls for Home Country GDP, Not Pregraduation Publications								
% of years abroad	−1.148**	−0.668	−1.075*	−1.361**	−1.017*	−0.213	−1.021	−1.295*
	(0.494)	(0.434)	(0.620)	(0.664)	(0.570)	(0.485)	(0.925)	(0.663)
H. Subsample from Low Article per Capita Countries, Controls for Home Country GDP and for Pregraduation Publications								
% of years abroad	−0.912**	−0.479	−1.324*	−1.622***	−1.017**	−0.154	−1.753*	−1.376**
	(0.429)	(0.394)	(0.683)	(0.568)	(0.487)	(0.485)	(0.993)	(0.556)

Significant at *10%, **5%, ***1%. Robust standard errors in parentheses. Cross-sectional are data collapsed to scientist level, and the dependent variables are averaged over years since the Ph.D. Estimated with the Mullahy model. Endogenous explanatory variable: % of years abroad. Instrument: Fulbright dummy. Exogenous explanatory variables: scientific field and Ph.D. year dummies, gender, ln(rank of Ph.D. institution) and GDP per capita of home country 5 years prior to graduation. In specified regressions, also include pregraduation total, first, and first high-impact publications.

geneity, we feel that the presence of a bias of a magnitude large enough to invalidate our results is unlikely in this sample.

Additional robustness tests. In this section we perform a variety of robustness checks. First, although we have clustered errors by individual to correct standard errors, we check whether we get similar results if we collapse the data to the scientist level (panels A–D of table 6). In this specification, the dependent variables are averaged over the years since receipt of Ph.D., and the key endogenous variable is the share of years spent abroad, instrumented by Fulbright status using 2SLS. The independent variables are the same as in our main results described previously.[42] This specification ignores all time-varying covariates, particularly how many years have passed since the Ph.D., due to collapsing the data. Thus, we lose information about which years the person is observed (since each scientist was not necessarily observed each year since Ph.D.). Nevertheless, the results in table 6 (panels A–D) are consistent with those obtained from the panel data, with large, significant effects associated with spending more years abroad for scientists from poor countries and insignificant or positive effects of being abroad for scientists from rich countries. The key difference is that now the impact on last-authored publications and on cites to those publications is only sometimes significant.[43]

It may be that the aspect of countries most important to the success of scientists located there is not their GDP but instead the commitment of the country to basic science and research. In panels E to H of table 6, we divide countries based on the number of scientific articles per capita pro-

[42] These are program rank, field dummies, Ph.D. year, GDP per capita of home country five years prior to Ph.D., gender, and pregraduation publications for specified regressions.

[43] An even more stripped-down specification would ignore all covariates and calculate the Wald estimator of the average difference in publications between pairs divided by the difference in the average share of years abroad, or its equivalent, 2SLS estimates similar to those above with no covariates. Not only does this ignore information about the timing of location and publication measures, but to estimate separate impacts of those from rich and poor countries, it requires us to drop all pairs with one person from a rich and the other from a poor sample—approximately 40% of the sample. As a result, we do not include the results in detail here. Not surprisingly, standard errors are quite large. Results give a consistently negative effect of the share of years spent abroad for low-income countries that are larger in absolute value than those for high-income sample, although only total and last-authored publications are significant at standard levels. For high-income countries, the effect of foreign location varies in sign and never approaches significance.

Table 7—Estimation of Effect of Being Abroad Using Alternative Matching Methods

	(1) Total Publications	(2) First-Authored Publications	(3) Last-Authored Publications	(4) High-Impact Publications	(5) Total (fwd) Citations	(6) Cites to First-Authored Publications	(7) Cites to Last-Authored Publications	(8) Cites to High-Impact Publications
				A. Matching on Pr(Fulbright)				
LAGFORLOC	−0.299	−0.370	−0.134	−0.395*	−0.275	1.23	0.051	−0.441
	(0.374)	(0.510)	(0.567)	(0.688)	(0.533)	(1.386)	(0.677)	(0.805)
				B. Matching on Pr(Fulbright), at Different Levels of GDP				
25th percentile	−0.777***	−0.640***	−0.760***	−0.836***	−0.873***	−0.337	−0.833***	−0.950***
50th percentile	−0.576***	−0.185***	−0.387	−0.626***	−0.645***	1.061	−0.527	−0.709***
75th percentile	−0.268	0.627	0.357	−0.248***	−0.155	4.388	0.141	−0.288
90th percentile	−0.010	1.390	1.111	−0.108	0.369	8.192	0.861	1.946
				C. CEM Matching				
LAGFORLOC	−0.890	−0.010	−0.857	−1.803	−0.599	1.225	−0.524	−1.193
	(0.622)	(0.743)	(0.725)	(1.180)	(0.752)	(1.561)	(1.212)	(1.048)
				D. CEM Matching, at Different Levels of GDP				
25th percentile	−0.822***	−0.428	−0.929***	−0.941***	−0.834***	2.779	−0.935***	−0.950***
50th percentile	−0.654***	0.147	−0.757***	−0.856***	−0.572*	2.959	−0.653	−0.805***
75th percentile	−0.392	1.070	−0.310	−0.691	−0.046	3.119	0.439	−0.380
90th percentile	−0.169	1.873	0.235	−0.528	0.489	3.210	2.169	0.180

Significant at *10%, **5%, ***1%. Robust standard errors clustered by scientist in parentheses.

duced by the country obtained from NSF (2008) as a proxy for this commitment. High article-per-capita countries are defined as countries whose articles per capita are above the 75th percentile.[44] We find results very similar to the results in the previous panels A to D based on GDP per capita.

We also pursue two alternative matching approaches to correct for the possibility that Fulbrights and controls are fundamentally different. Our preferred matching procedure is as described throughout the paper, where we match exactly on Ph.D. institution and field of study and nearly exactly on year of graduation. However, it is possible that by choosing to match exactly on these covariates, we have neglected other factors that could introduce bias—for example, the research productivity of the student while in graduate school.

Our first alternative matching approach is matching each Fulbright to the non-Fulbright who is the closest to that person in terms of the predicted probability of being a Fulbright. Each of our Fulbrights is matched to the control student in the same broad scientific field with the closest predicted probability of being a Fulbright as based on a logit model of Fulbright status as a function of the exogenous variables previously used. We think of this as a way of collapsing the observable characteristics correlated with Fulbright status into an index that can then be used to identify the most similar control to the Fulbright in question.[45] The average matched control appears 2.3 times. All covariates are balanced (i.e., there is no statistically significant difference in the means of these covariates for Fulbrights and controls).

The second alternative matching procedure approach is based on the coarsened exact matching (CEM) procedure used by Azoulay, Graff-Zivin, and Wang (2010) following Iacus, King, and Porro (2012). In this nonparametric procedure, one selects a set of covariates—in our case, the scientist's field of study, the GDP per capita of the home country (five years before the Ph.D.), the number of first-authored articles written while in graduate school, the year of graduation, and the rank of the Ph.D. program—and creates strata with an approximate (or "coarsened") match on these covariates. For each treated observation (where treatment in this case is Fulbright status), a matching control observation is drawn from within its stratum, and nonmatching observations are dropped. The average matched control appears 1.42 times in the new data set. All covariates are balanced, with the exception of the log of the home country GDP per capita.

For each of these matching methods, we run two sets of regressions (using the Mullahy estimation procedure). In the first, each of our eight research output variables is modeled as a function of LAGFORLOC and the same set of controls used in the main analyses in table 4. In the second, we run the standard dependent variables on LAGFORLOC and the (lagged log) GDP per capita of the present country, both instrumented as in our table 4 results. The results appear in table 7. The substantive differences from table 4 are that the average impact of being located abroad is no longer significant, with the exception of high-impact publications in panel A (significant at the 10% level). This may be partly due to the reduction in the sample size. However, the estimates in panels B and D continue to display large negative impacts of being located in low-income countries, and no significant effect of being located in high-income countries.

[44] Specifically, a scientist is classified as coming from a high article-per-capita country if the scientist's home country is above the 75th percentile of articles per capita in the year of graduation.

[45] This is similar to propensity score matching, but the matching is with respect to the propensity to be a Fulbright (the instrument) rather than with respect to the propensity to be abroad (the treatment). More details about both matching methods are included in the online appendix B.

C. *Effects by Field of Study*

It is possible that the impact of foreign location depends on the field. We therefore experimented with several different interaction terms between fields and foreign location in our total publication equations. One question we asked was whether the negative impact of foreign location was limited to fields dependent on large laboratories—19% of our sample. We found that in fields with or without big labs, the negative impact of foreign location was strongest in poor countries. However, total and first publications and citations in large-lab fields were less disadvantaged than other fields (at all income levels). In contrast, foreign location negatively affects last-authorship and high-impact authorship in large-lab fields in both poor and rich non-U.S. countries. Since last authorship in science signifies the laboratory head, this suggests that people in large-lab fields are participating in others' labs (perhaps in the United States). These results are tentative since the scientists in our sample are for the most part in the early stages of their academic careers, at which time few can be expected to be heads of large labs.

Another question we investigated was whether foreign location increased publications for those in agricultural and related fields (such as water resources and entomology) because many countries of origin are more rural than the United States, and this might be counteracting larger negative effects in other fields. Dividing the impact of foreign location by whether the field was related to agriculture, we find that the significant negative effect is indeed in the non-agricultural fields. but that this too was true only for poor countries. We found that the impact of foreign location was insignificant in agricultural fields, with the exception of last-authorship and a marginal effect of total cites in the very poorest of countries; signs were often positive. As a result, excluding agricultural fields led to somewhat larger and more significant effects than seen in table 4. The agricultural results should be interpreted carefully since only 12% of observations are in the agricultural fields.

V. Conclusion

In this paper, we have examined whether newly minted U.S. Ph.D.s of foreign origin maximize their post-Ph.D. contributions to science if they remain in the United States. Others have documented that the high concentration of star scientists and excellent universities in the United States seems to have led to positive externalities for others' research productivity. This suggests that foreign-born recipients of U.S. doctorates who return to home countries will be less productive than they would have been in the United States. Additional advantages of U.S. location include financial resources, access to top journals and conferences, a culture of research competitiveness, and business support of basic research.

This paper compares publication histories for a sample of U.S. Ph.D. recipients from abroad using exogenously determined variation in post-Ph.D. location to identify the causal effect of location on research output. The results suggest that those who remain in the United States are at an advantage in terms of higher rates of publications, citations and familiarity with recent literature compared to those in countries with low GDP per capita. This is particularly true in terms of publishing highly cited science in high-impact journals. However, we cannot reject the hypothesis that those in countries with high GDP per capita, especially countries in the top decile of GDP per capita, are just as likely to publish, to be cited, and to remain current as those remaining in the United States.

One caveat to the conclusions in this paper is that we have sampled only foreign-born scientists who received their Ph.D. education in the United States. These scientists are more likely than their compatriots to retain links to the U.S. research world and therefore may be less affected by their location outside the United States. Conversely, their productivity may suffer more from being abroad due to the lack of a local scientific network built up during graduate studies. In our future research, we will study the networks of international collaboration and citation of our U.S.-educated sample of those who are foreign born, measuring how links to the United States and other countries develop and grow, depending not only on the scientists' location but also on their fields, employment sector, and research abilities.

Overall, our findings suggest that a scientist exogenously located in a country high in the income distribution can expect to be as productive in research as he or she would be in the United States. This finding is fairly surprising in light of the high degree of concentration of top scientists at U.S. universities. It may reflect the mitigating factors discussed in section II, particularly other countries' increasing commitment to excellent science and to higher levels of science education, as well as easier international collaboration made possible by technological developments and encouraged by global "brain circulation" of U.S.-educated Ph.D.s returning to their home countries.

Our results have implications for both the future of global knowledge creation and the future of the position of the United States in the international scientific hierarchy. As less wealthy countries' per capita GDP converges toward wealthier ones, the productivity of scientists located in those countries can be expected to also converge toward U.S. levels. This could vastly increase the number of scientists around the world conducting cutting-edge scientific research. As a result, global knowledge will expand at increasing rates. However, our results suggest that the United States is able to attract many of the world's top scientists because many people enjoy living here, because many foreigners receive their Ph.D.s here and most stay, and because there remains considerable U.S. government financial support for basic scientific research—*not* because being located in the United States makes scientists more productive than they would be in another high-income country. If governments in Asia and Europe increase their efforts to lure scientists to their countries, particularly by offering large amounts of financial support, and continue to expand and improve their own Ph.D. programs, our findings suggest that the United States could lose its position of dominance in scientific research.

The United States will remain at the forefront of science only if it can continue to attract excellent STEM students to its graduate programs and if a large proportion of these graduates continue to choose to live in the United States. This will require both continued government support of excellence in graduate science education and redoubled government efforts to fund scientific research.

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APPENDIX TABLE

First-Stage Regressions of Lagged Non-U.S. Location

	Full Sample	Full Sample, Including Interaction with GDP		Subset: Rich Home Country	Subset: Poor Home Country
Dependent Variable	LAGFORLOC (1)	LAGFORLOC (2)	LAGFORLOC X ln GDP (3)	LAGFORLOC (4)	LAGFORLOC (5)
Fulbright dummy	0.368***	0.371***	3.355***	0.261***	0.396***
	(0.0362)	(0.0359)	(0.340)	(0.0585)	(0.0493)
Real percapita GDP home country 5 yrs pre-Ph.D.	0.0457**			−0.154	0.0944***
	(0.0192)			(0.101)	(0.0291)
Biological sciences	−0.211***	−0.214***	−1.791***	−0.121	−0.234***
	(0.0632)	(0.0634)	(0.577)	(0.103)	(0.0811)
Engineering & Computer Science	−0.123**	−0.127**	−0.951*	−0.112	−0.0990
	(0.0613)	(0.0612)	(0.555)	(0.0921)	(0.0795)
Earth/Air/Ocean Sciences	−0.0606	−0.0646	−0.400	−0.0199	−0.0455
	(0.0855)	(0.0853)	(0.816)	(0.134)	(0.110)
Mathematics & Statistics	−0.0744	−0.0768	−0.514	−0.0609	−0.120
	(0.0823)	(0.0825)	(0.763)	(0.110)	(0.122)
Physical Sciences	−0.159**	−0.162**	−1.274*	−0.183*	−0.0677
	(0.0790)	(0.0788)	(0.750)	(0.0992)	(0.112)
Psych. Research	−0.142	−0.149	−0.888	0.129	−0.441***
	(0.140)	(0.139)	(1.408)	(0.169)	(0.101)
Environmental Science	−0.0722	−0.0741	−0.435	0.0225	−0.0647
	(0.0980)	(0.0977)	(0.899)	(0.205)	(0.114)
Year of Ph.D. = 9798	0.183***	0.177***	1.651***	−0.0290	0.277***
	(0.0605)	(0.0608)	(0.574)	(0.1000)	(0.0739)
Year of Ph.D. = 9899	0.0588	0.0546	0.513	−0.00851	0.0731
	(0.0489)	(0.0489)	(0.464)	(0.0920)	(0.0563)
Year of Ph.D. = post02	−0.0665	−0.0673	−0.635	−0.204**	−0.0524
	(0.0727)	(0.0732)	(0.686)	(0.103)	(0.0813)
Year of Ph.D. = pre96	0.233***	0.221***	2.155***	0.236**	0.194***
	(0.0505)	(0.0504)	(0.474)	(0.0971)	(0.0631)
Year = 9798	−0.130***	−0.123***	−1.260***	−0.202***	−0.0724**
	(0.0327)	(0.0329)	(0.314)	(0.0572)	(0.0370)
Year = 9899	−0.0298*	−0.0255	−0.277	−0.0397	−0.0274
	(0.0178)	(0.0180)	(0.172)	(0.0308)	(0.0213)
Year = post02	0.0570***	0.0480***	0.475***	0.0346	0.0724***
	(0.0153)	(0.0158)	(0.151)	(0.0262)	(0.0188)
Year = pre97	−0.0797	−0.0715	−0.815*	−0.147*	−0.0312
	(0.0506)	(0.0510)	(0.467)	(0.0834)	(0.0592)
ln(Rank of Ph.D. program)	−0.0104	−0.0105	−0.133	−0.0426*	−0.00696
	(0.0164)	(0.0165)	(0.156	(0.0243)	(0.0221)
Female	0.0336	0.0334	0.299	−0.0788	0.110*
	(0.0505)	(0.0501)	(0.481)	(0.0727)	(0.0613)
Lagged GDP per capita of home country		0.0463**	0.759***		
		(0.0193)	(0.173)		
Constant	−0.0925	−0.104	−4.076**	1.946*	−0.531**
	(0.182)	(0.186)	(1.642)	(1.023)	(0.242)
Observations	4,339	4,339	4,332	1,692	2,647
R^2	0.210	0.210	0.220	0.199	0.286

Significant at *10%, **5%, ***1%.