Does US Science under-invest in International Post-Doctoral Scholars? Evidence from the ECDS

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Abstract: We investigate investment in postdoctoral researchers at US academic institutions using new data from the NSF's Early Career Doctorates Survey. We observe differences in the experiences of temporary resident postdocs compared to US citizen and permanent resident postdocs. The development of independent research careers among temporary residents is less supported, while their work is more closely monitored and their salaries are lower. They are more motivated to take a particular postdoc by its prestige, and less likely to take it to work for a specific person or to have the opportunity to do independent research. Differences are typically larger for temporary residents who are required to leave the US because of their visa status.

The US STEM workforce is heavily reliant on skilled workers who come to the US from abroad. Prior literature has focused on the roles and impacts of foreign-born scientists who come to the US to obtain PhDs as well as those who are trained abroad and enter the US on work visas such as the H-1B to join academic institutions or for-profit firms.[1] However, there has been little research on post-doctoral scholars (or postdocs) who come to the US with a PhD from a foreign institution – a glaring omission because a large share (38%) of post-doctoral scholars in the US obtained their PhD degrees abroad.

Postdocs receive training and career development, but also supply labor in research labs led by PIs. The balance of training and work may differ across postdocs and PIs. Several studies have identified broad problems with the post-doc model: Stephan (2013) describes the low pay and long hours worked by postdocs in the US, and both Stephan and Ginther & Kahn (2017) describe the low probability of postdocs finding tenure-track academic jobs. Sauerman and Roach (2016), in a survey of postdocs, found them quite well-informed about this low likelihood of entering full-time research positions 5 years post-graduation. In contrast, Ganguli et al. (2021) find that chemistry PhD students tended to be overly optimistic about the chances of academic jobs post-postdoc, particularly foreign students, and this leads them to enter postdocs. Finally, both Grinstein & Treister (2018) – based on a small 190 person survey – and Bentham et al. (2020) based on large Canadian surveys – documented the low levels of satisfaction among postdocs ("a surprisingly unhappy postdoc community") and reasons for this dissatisfaction.

Research on international postdocs in the US has been hampered by the lack of information about postdocs in the US with non-US degrees. Black & Stephan (2010) – using a novel way of estimating authors' nationality – found that foreign postdocs and graduate students in the US had publication records approximately proportional to their numbers; Cooley and Sabharwal (2007), using the NSF SDR, also found them equally productive in terms of articles, but foreign postdocs were more productive in terms of patents.

However, international postdocs are typically reliant on temporary visas tied to the employer, and Hayter & Parker (2018) – in a small survey 97 postdocs and 35 PIs – found qualitative evidence that international postdocs are "exploited" due to this dependence on PIs for the renewal of short-term visas.[2] An earlier and even smaller survey of postdocs and faculty by Cantwell and Lee (2010) documented attitudes of US faculty that led to exploitation and long hours: the faculty believed international postdocs from Asia to be hard working but without strong ambitions for career advancement, so the faculty felt off-the-hook for training them to be academics.

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[1] E.g., Bound, Turner and Walsh 2009, Kahn and MacGarvie 2015 and 2019, Roach, Sauermann and Skrentny 2019, Hunt and Gauthier-Loiselle 2010, Kerr and Lincoln 2010, Mayda et al 2020, etc.

[2] This aspect of Hayter and Parker was highlighted by a Nature editorial entitled "Stop exploitation of foreign postdocs in the United States" (https://www.nature.com/articles/d41586-018-07479-7).

However, a systematic analysis of a larger, representative dataset is needed to assess whether US PIs do indeed under-invest (i.e. provide less training and career development) in foreign postdocs – with foreign or US PhDs – and if so, identify potential explanations for this under-investment.

Temporary visa status may allow exploitation of postdocs because their visa status ties them to the employer. However, whether that exploitation turns into differential treatment of and underinvestment in temporary residents (in addition to the typically lower salaries paid people required to stay with a single employer) depends on the role that postdocs play in the supervisor's research, and more generally on what supervisors hope to gain from their postdocs. Postdoc supervisors often view their postdocs (even more than graduate students, in some fields) as their intellectual children, their future legacy to the field, as well as future collaborators. If PIs anticipate a disruption in their relationship upon foreign postdoc's return to the home country, this reduces their incentives to invest in them. Other possible reasons for different treatment may be particular to foreign-*trained* postdocs, who represent approximately 35% of our sample. Supervisors may believe that foreign-trained postdocs have lower productivity and/or less understanding of research practices than domestically trained post-docs, leading supervisors to give them less independence and lesser roles than those trained in the US. Finally, postdocs trained outside the US are less well informed than US citizens about the nature of postdocs in the United States, making mismatch between postdocs and supervisors more likely. Moreover, mismatch may also occur between US-trained temporary resident postdocs and their supervisors due to cultural differences.

This paper measures under-investment in international postdocs and differentiates between candidate explanations for it, using some of the richest and most detailed data available on postdocs. The NSF's Early Career Doctorates Survey is designed to provide nationally representative statistics on recent doctorate (or equivalent) recipients working at U.S. masters-or-doctorate-granting academic institutions (excluding medical schools and centers) and federally funded research and development centers (FFRDCs). Unlike the NSF's Survey of Doctorate Recipients, it includes doctorates who received degrees in any country. The ECDS is particularly useful because it contains: (a) detailed data on postdocs' visa and citizenship status, countries of origin, location of PhD, and plans for future employment and future location plans; (b) rich information on researchers' productivity in the form of patents, publications, proceedings, and submissions and (c) survey questions describing the extent and type of supervisor mentoring, training and activities during postdocs.

Also of particular interest are the ECDS questions that ask about the factors affecting the postdoc's decision to stay in the US or return home. The latter reasons include visa and immigration barriers, a highly

important topic but one about which there is little direct evidence on the actual impact of visas on location choices.[3]

The ECDS includes people in the first 10 years post-PhD. We limit our analysis to a subset of these, those who report being currently in a postdoctoral position.[4]

Data and Empirical Approach

In the analysis discussed below, we use the subset of respondents to the 2017 and 2015 ECDS who are currently postdocs.[5] Note that we cannot use the ECDS to learn about those in industry postdocs, because of the ECDS's sampling frame is limited to academia and research centers. Over the two years, the ECDS surveyed 3,648 individuals, most of whom were surveyed in 2017.

In what follows, we will examine differences in investment in postdocs' careers between US citizens or permanent residents with US PhDs and temporary residents with US PhDs or temporary residents with Foreign PhDs. (For simplicity, from here on we will use the term "US citizens" to include permanent residents.) US citizens/permanent residents with foreign PhDs comprise a small part of our sample, and while we control for this category with a dummy variable, we do not analyze patterns for this group separately due to the small number of observations on these people in our sample.[6] Table 1 gives some summary statistics about the variables used in this study, divided into these four groups.

Dependent Variables measuring Postdocs' Activities and Supervisors' Investment

Our main dependent variables describe postdocs' activities, the training they receive, and their descriptions of their supervisors' interactions with them.

First, we measure whether postdocs have engaged in activities directly related to scientific careers including if they:

- Submitted and published papers in journals and proceedings, gave presentations, and filed patents[7]
- Taught courses
- Served as the principal or co-investigator on a grant proposal

[3] In our prior work (Kahn and MacGarvie 2019), we found that recipients of US PhDs who were subject to longer waits for permanent residency had lower stay rates.

[4] For reasons relating to the way the data are reported, we also limit the 2015 wave of the survey to individuals who have been in no more than three different positions after their PhD. This results in dropping 26 observations, or 1.5% of postdocs from the 2015 wave of the survey.

[5] The 2015 data are limited to individuals who have had fewer than 4 positions since PhD completion.

[6] We have found that most differences between this group and US citizens with domestic degrees are explained by selection and shrink considerably with controls for productivity and other factors.

[7] In some cases we observe whether or not they are involved in publishing, and in other cases we analyze the number of articles published.

We also examine the extent of agreement with the following statements about supervisors' support during the postdoc, where 1 equals "Strongly disagree," and 5 equals "Strongly agree".

- Career Advice = your supervisor provides career guidance.
- Collaboration = your supervisor encourages collaboration.
- Independence your supervisor encourages increasing independence in your research or work.
- Grant proposals= your supervisor provides opportunities to work on grant proposals
- Support for publishing = your supervisor supports publishing papers or presenting your work.
- Recognition = your supervisor provides appropriate recognition for your work.
- Work/Life Balance = your supervisor encourages work/life balance.

We look at working conditions, as measured by salary, hours worked, and job satisfaction (rated on a scale from 1 (very dissatisfied) to 5 (very satisfied). The stressfulness of the position is rated from 1 (not at all stressful) to 5 (extremely stressful).

The extent of PI monitoring of the respondent is measured via several variables. A survey question asked respondents how frequently they met with their supervisor to discuss their work (not counting lab or department meetings). We create a dummy equal to 1 if the respondent meets the supervisor at least once a week. Another dummy captures whether the respondent had a formal performance evaluation in their current position. We ask whether the respondent has had a recent performance evaluation, whether they have a written work plan, and whether this work plan incorporates their personal goals ("How much does your work plan reflect your personal career development goals? 1=not at all, 2=somewhat, or 3=a great deal?"). We analyze mentorship via a dummy equal to 1 if the respondent has any mentors, and 0 otherwise. Another dummy equals 1 if the respondent has supervised another person in their current job.

We also examine a series of questions that capture whether a respondent's expectations were met with regard to several aspects of their work. The question asked "How much did this position meet your expectations with regard to…" and we coded dummy variables equal to 1 if the respondent indicated "less than expected" about the following items:

- Collaborate and network with colleagues
- Present papers at professional conferences
- Write grant proposals
- Publish papers
- Conduct your own independent research
- Increase your subject matter knowledge
- Supervise others
- Teach courses

Control variables

Control variables include gender, race (a non-white dummy, of which 82% are Asian), language (English first language), and the number of years since PhD completion. We also include dummies for year of the survey and field of study.

We also control for several productivity measures, except when the dependent variable is publications. These measures include:

- Accepted Publications (the number of publications submitted and accepted since doctoral receipt) and Submitted Articles (the number of publications submitted since doctoral receipt);
- Proceedings (the number of publications in conference proceedings since doctoral receipt;
- Patents (the number of patent applications filed since doctoral receipt), and
- Presentations (the number of papers presented at conferences since doctoral receipt).

Network variables

Variables measuring the extent of the person's social/professional networks serve as dependent variables, but also are included as control variables in regressions of other dependent variables. The ECDS asks for the primary way in which the respondent found their postdoc position, and this no doubt reflects differences in the pre-existing social networks of citizens and temporary residents. Wei et al. (2012) found that US postdocs were more likely than international postdocs to use personal networks to find a job. This may result in better matching between citizen postdocs and supervisors, and US postdocs may be better informed about what to expect before they begin working in a new position. The variable "personal networks" equals 1 if the respondent found the job through a graduate advisor, mentor, colleague, peer, family member or friend. Another control variable measuring networks is a dummy equal to 1 if advertisements were the primary way the respondent found their current job.

Other survey questions related to networks investigate the reasons for taking the current job, allowing respondents to choose more than one reason. The two reasons we control for are "to work with a specific person," and "prestige." We expect that respondents who took the job to work with a specific person must be more professional connected to begin with. This is likely to make them better matched with their supervisor. As a result, they are likely to have better a relationship with their supervisor, or may be better informed about what to expect in their postdoc, while those who sought out the job primarily for prestige could have less personal connection to the supervisor and less well-matched.

Visa and Location preference variables

The ECDS has data on the specific kind of visa a person has. Not only do we know whether the postdoc is on a temporary visa, but we also know the specific type of visa. We separate out those on J-1 visas, since they are

required to return to their home country for at least 2 years when the visa expires, and denote it "Required to leave." In the 2017 survey, 59% of temporary residents were on a J-1 visa, 10% were on a student (F) visa, (probably in their 3 years of OPS), and 27% were on H-1B visas. The great majority of those on J-1 visas were foreign PhDs (78%) compared to those on other visa's (with only 18% foreign PhDs). This makes it difficult to separate out effects of having received a PhD outside the US and being required to leave the US after the post-doc. In our regression sample, there are 1,619 native US citizens and permanent residents who obtained PhDs in the US, 168 citizens and permanent residents who obtained PhDs abroad, 611 temporary resident who obtained PhDs in the US, and 1,267 temporary residents who obtained PhDs abroad.

The ECDS also includes the question "Thinking about the next 10 years, where do you plan to pursue your career? Would you say..." and the choices given are in the US, abroad, or both in the US and abroad. The variable "Plans to leave" takes the value of 1 if they reply "abroad."

Results

Networks

We begin by investigating differences in networks. The overall percentage of respondents who found their jobs through personal networks is 34.5%, and 67.8% of the sample were motivated to take the job to work with a specific person. Overall, 23.5% of the sample found their job through an advertisement, and 70.5% were motivated by prestige in taking their job.[8] Table 2 presents the results of regressions where the dependent variables relate to networks and the key explanatory variable is whether the postdoc is a temporary resident. Temporary residents are 4.55 percentage points (*pp*, with a standard error of 1.9 *pp*) less likely to say that they found their current job through personal connections and 6.57 *pp* (se=3.1) more likely to have used an advertisement to find their job, compared to citizens. After adding controls, the differences are somewhat less clear. Temporary residents not required to leave remained a significant 6 *pp* more likely than citizens and permanent residents to have used an advertisement to find their job, and perhaps also less likely to have found their jobs through a network (t=1.63). No differences between those not required to leave and citizens/permanent residents in job-finding methods were identified. However, the differences by race were very strong. Non-white respondents were 3.93 *pp* less likely (standard error 2.2 *pp*) to have used personal networks to find their job, and 6.77 *pp* more likely to have used advertisements.

Survey respondents were allowed to specify more than one reason for taking the job, and far more (8 percent) temporary residents than citizens said that they took the job for the prestige it confers. With controls added, this is shown to be driven by those required to leave (mostly having had non-US degrees) who were 7.97

[8] Respondents can select more than one motivation for taking their current job.

pp[9] more likely than citizens to have been motivated by prestige (standard error 2.7 *pp*, so significant at the 1% level). (This reason for taking the job does not differ by race.)

Fewer temporary residents than citizens report that they took the job to work with a specific person, but with controls this is no longer true, and instead there are large differences between those required to return being more likely to do so than other temporary residents. A more significant factor is race, with non-whites 6.01 percentage points less likely to take the job to work with a specific person. A regression with country of origin fixed effects reveals that the origin countries with the lowest negative (and significant) coefficients are China, Japan and South Korea.[10]

In the regressions described below, we use these network variables as controls, in addition to the control variables described above (J-1 visa, English first language, female, non-white race, years from PhD, and field and survey-year fixed effects).

Differences in supervision, activities and training between temporary residents and citizens in postdocs

Table 2 describes how activities, training, supervision and subjective experiences differ between temporary and postdocs with regard to 4 main areas: Publishing, Grants, Teaching and Collaboration/Mentoring. Table 3 presents these results.

When we look only at the average differences between postdoc experiences of temporary residents and citizens – without any controls – most are large and significant, and disadvantage temporary residents.

Productivity, and specifically the number of publications submitted and accepted since doctoral receipt, is likely to jointly capture a person's ability and productivity, and supervisors' emphasis on publications. This is the one area where temporary residents seem to have an advantage on average. They publish more than citizens and have received more training in publishing.

In most other aspects of postdocs, on average temporary residents are disadvantaged relative to citizens. They are 7.51 percentage points less likely to have a mentor. They are 14.8 *pp* less likely (standard error 2.0 *pp*) to have served as a PI or co-PI on a grant, a very large difference since only 40% of our sample on average have done so at this stage of their career. (They are, however, equally likely to receive training in grant-writing.) Temporary residents are less likely to have taught a course, or to have received training on teaching. However,

[9] In the tables, the difference between citizens and temporary residents with J-1 visas is the sum of the two coefficients, on Non-US citizen and on "Required to leave."

[10] This regression is not reported in the tables but is available upon request. We included fixed effects for the major sending countries: Canada, China, England, France, Germany, India, Italy, Japan, and South Korea. All other countries were grouped together in the "other" category. The choice of countries was dictated by the way the data are reported in the ECDS.

they are also less likely to have taken their current job in order to teach. Their supervisor is less likely to have supported their publishing and presenting, or to have provided opportunities to work on grant proposals.

On average, the activities of temporary residents are more monitored and directed by their supervisors: They have more frequent meetings with their supervisors; they are more likely to have been given a written work plan; and conditional on having a work plan, the plan is less likely to reflect their personal career development goals. They themselves are much less likely (13.4 *pp*) to have supervised others.

Finally, temporary residents are paid 5.85 percentage points less than citizens (se 1.1).

Multivariate analysis shows, however, that a good number of these differences are partially or completely tempered by other characteristics (gender, years since PhD, field, race, survey year, networks, English first language), although a few are not. In addition, many of these differences are more prevalent for those required to leave the US (i.e. have J-1 visas) than for other temporary residents. Being nonwhite and being a native English speaker often picks up what had been attributed to temporary residency.

Even with controls, temporary residents remain 6.17 *pp* less likely to have a mentor than citizens (se 2.6 *pp*). This is even more true for temporary residents required to leave, who are 9.10 *pp* less likely to have a mentor.

Temporary residents remain more likely than citizens to have published even with controls, although this difference is less significant for non-J-1 temporary residents (t= 1.83) and even smaller and insignificant for J-1 visa holders. With controls there is no evidence that being a non-citizen *per se* leads them to receive more training on how to publish. Instead it is non-native English speakers and non-white postdocs who receive more training on publishing, which may be designed to improve their writing skills in English.

With controls, temporary residents are still less likely than citizens to have been a PI/co-PI on a grant, although this difference is much smaller than previously for non-J-1's (5.83 *pp* with t=1.82), but more substantial for J-1s (10.71 *pp*). Race plays a large role as well, with nonwhites 7.18 *pp* less likely to have been on a grant. Only J-1's are less likely than citizens to receive training in grants as citizens, and this difference is large (9.34 *pp*.) As with publishing, non-native English speakers receive more training in grant writing.

Temporary residents remain less likely to have taught than citizens even with controls, and much more so for those required to return than for other temporary residents (11.85 *pp*. with a t of 4.37 v 5.51 *pp* (t only1.84).

Even with controls, differences in supervisor encouragement remain significant in some cases: supervisors are less likely to encourage temporary residents required to return to publish (compared to citizens).

Adding controls narrows the differences in monitoring of temporary residents v. citizens and permanent residents. The only significant differences remaining are between J-1 visa holders and citizens/permanent

residents, who are less likely than to supervise others (9.10 *pp* with a t=3.64). Temporary residents who are not J-1 visa holders may also be less likely to supervise others, but the difference is not significant at the 5% level. (4.47 *pp* t=1.72). Non-white race is much more important in explaining higher monitoring frequency, both in terms of meetings and performance evaluations. How concerning this is depends on one's view of whether more frequent monitoring is good or bad. Non-white respondents do not, however, report differences in the extent to which the work plan incorporates their personal goals, nor do they experience differences in the extent to which the supervisor encourages independence, all else equal.

With controls, pay is not significantly lower for temporary residents not required to leave than for citizens. It is, however, 2.87 *pp* lower for those required to leave (but not significantly, with a t of 1.60). Native English speakers earn 5.53% more than others, but also work more hours than others.

Differences in subjective experiences

Did temporary residents expect the kinds of postdocs that they got? The estimation suggests they did not, along several dimensions. Concentrating on results with controls to pinpoint exactly who feels disappointed, we see that all temporary residents (J-1 and not) wrote fewer grant proposals and did less teaching than they expected to, and J-1s in particular published fewer papers than they expected to during their postdocs (6.94 *pp* with a t of 2.90).

While, on average, temporary residents are less satisfied overall with their jobs than citizens (0.174 on the Likert scale), this difference disappears with controls. However, there *is* a wide difference between non-native English speakers and native English speakers, which includes most citizens. Among citizens, 78% are native English speakers, and 87% of native English speakers are citizens or permanent residents.

Finally, we note that temporary residents not required to leave seem to be more likely than citizens to feel their supervisors recognize their work contributions (t=1.88). This is not the case for temporary residents required to leave.

Plans to leave

We now turn to understanding the relationship between experiences in a US postdoc and the decision to leave the country after completion of the postdoc. To do this, we analyze a question that asked respondents "Do you plan to leave the United States in the next ten years?" using a dummy equal to 1 if the respondent answered "Yes" to this question. We run OLS regressions in which "Plan to leave" is the dependent variable, and independent variables include the usual set of controls for productivity, networks, personal characteristics and field of study. We restrict this analysis to those who are not US citizens or permanent residents. In this group, the overall percentage who plan to leave is 22.9%. It is worth noting that 32.4% of our sample responded to this

question with "Don't know." This response is coded as zero (similar to those who respond that they do not plan to leave the US) in the results presented here. Results are broadly similar when "don't know" is coded as missing.

Not surprisingly, J-1 visa status is strongly correlated with plans to leave. Holders of this type of visa are 13 to 14 percentage points more likely to plan to leave the US *ceteris paribus* (and 29.2% more likely to leave without controls). It is somewhat surprising that more J-1 holders do not report plans to leave the US. It is possible that respondents interpreted the question to mean "leave the US and not return," since 81.6% of J-1 visa holders responded that they planned to work in both the US and abroad in the next ten years (whereas only 29.2% of J-1 visa holders responded that they planned to leave the US).

The number of years from PhD is negatively associated with planning to leave, presumably as those who have stayed longer are more established in their positions and more generally ensconced in their locations. Productivity measures are not, perhaps surprisingly, significantly associated with plans to leave. This contradicts much of the literature on migration, for example Borjas and Bratsberg (1996). The personal characteristics race, language and gender are also not significantly correlated with the decision to leave.

The other variables which *do* explain plans to leave relate to their postdoc experiences, specifically overall dissatisfaction as well as less mentoring, less autonomy, lower supervisor support for collaboration. A one-unit increase in the satisfaction score is associated with a 2.0 percentage point decline in the probability of leaving (se. 1.0 *pp*). A one-unit increase in the measure of whether the work plan incorporates the respondent's personal goals is associated with a 5.49 percentage point reduction (s.e. 2.2 *pp*) in the leave probability, while increases in the supervisor's recognition and encouragement of collaboration are associated with declines in the leave probability of 2.86 percentage points (s.e. 0.9 *pp*) and 1.96 percentage points (s.e. 0.9 *pp*) respectively. Predictors which are negative and significant at the ten percent level are having a mentor, receiving training for teaching, and receiving training for publishing.

Implications

In summary, we find that on average temporary residents report less activity, training, and encouragement as well as unmet expectations with regard to publishing, grants, teaching and collaboration/mentoring. Drilling down by controlling for personal characteristics and visa type shows evidence about why this may be the case. Their differential treatment does not seem to be about lower productivity, since temporary residents are more likely to have published, and have higher numbers of publications in journals and proceedings, and submitted articles. They have similar numbers of patents, all else equal.

Some of the differential treatment (or perception of differential treatment) *does* seem to be particular to those who, for visa reasons, must return home. All temporary residents are less likely to have mentors (even with all controls), and this is more true for those required to return. All temporary residents are less likely to have been

PIs or co-PIs on grants, and this is more true for those required to return. All temporary residents are less likely to have taught courses, and this too is more true for those required to return. Those required to return are less likely to be encouraged to publish. Temporary residents required to return are monitored more closely by their supervisors than citizens. Temporary residents required to return are paid less than citizens. Temporary residents are less likely to have supervised others, and this is particularly true for those required to leave. Some of the worse treatment of those required to return might be because supervisors are less invested them, although some might be due to the fact that this group is more likely to have foreign training.

Being nonwhite and not being a native English speaker often pick up what had been attributed to temporary residency. It is important to note that differences attributable to non-white race are entirely driven by temporary residents, and when we interact non-white with citizenship status, we find no significant differences in our key variables between white and non-white US citizens and permanent residents. When, in an alternative specification, dummy variables for country of origin are added, the effects of non-white race are partially explained by being originally from an Asian country. For example, the coefficient on nonwhite in the regression measuring whether a respondent has supervised others falls from -0.0817 to -0.0410 when controls for countries of origin are added, and the coefficient on the dummy for China is -0.1122 (with a t of 1.81). This implies that Chinese postdocs who are not required to return are 19.94 *pp* (t=2.85) less likely than white US citizens or permanent residents to supervise someone, while Chinese postdocs required to return are 25.50 *pp* (t=3.61) less likely than citizens/permanent residents to have supervised someone in their current position. Similarly, Chinese postdocs not required to return home are 19.14 *pp* (t=2.38) less likely to have been a PI or co-investigator while those Chinese required to return home are 25.09 *pp* (t=3.10) less likely to have been a PI. Chinese postdocs have the second lowest levels of satisfaction (3.75 on average) among temporary residents (and they are very close to the lowest: 3.72, among postdocs from Japan). The average satisfaction rating among US citizens and permanent residents is 3.97, and among Canadian postdocs (the happiest) it is 4.12.

There is evidence that international post-docs are less likely to exploit personal networks to find their jobs, and more likely to rely on arm's length advertisements. This explains some of our findings. For example, those who took their job to work with a specific person have significantly higher job satisfaction, are less likely to be disappointed about opportunities for collaboration, and are more likely to perceive that their supervisor provides recognition for their work. Given that these variables are predictive of staying in the US, improving the match between post-docs and their supervisors may yield benefits not only for the individual post-doc but also from the perspective of retaining scientists in the US who would otherwise leave the country after their postdocs.

Additionally, US institutions should ensure that international post-docs have equal access to all aspects of training and mentoring. Experience with grant writing is a particular area in need of attention. It is also one of the variables that seem to be causally explained by being required to leave the US. It is particularly striking that most

of the differences we observe capture aspects of personal relationships: collaboration, teaching, mentoring, supervising. International post-docs who report positively about these relationship variables, who feel encouraged by supervisors, who have more autonomy, and are generally more satisfied are more likely to choose to remain in the US. Ensuring equal treatment may thus increase retention of foreign post-docs and help the US compete for high-skilled workers.

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Table 1: Mean values of variables on Postdocs in the Early Career Doctorate Survey, 2015 & 2017

	US citizens /perm. res., US PhDs	US citizens/perm. res., Foreign PhDs	Temp. res., US PhDs	Temp. res., Foreign PhDs
Years since PhD	2.807	4.872	2.269	2.904
Non-white*	0.298	0.515	0.836	0.610
English first language*	0.788	0.297	0.102	0.108
Female*	0.524	0.556	0.333	0.339
Plans to leave*	0.004	0.084	0.157	0.272
J-1 visa*	0.000	0.000	0.188	0.777
Found job through network*	0.371	0.252	0.351	0.325
Found job through advertisement*	0.201	0.290	0.291	0.250
Took job to work with specific person*	0.701	0.645	0.643	0.687
Took job for prestige*	0.664	0.657	0.744	0.752
Grant activity*	0.490	0.464	0.343	0.345
Grant training*	0.374	0.387	0.403	0.348
Supervisor encourages grants†	3.848	3.792	3.736	3.680
Unmet expectations about grants*	0.215	0.303	0.361	0.291
Publishing activity*	0.829	0.848	0.885	0.865
Publishing training*	0.216	0.296	0.289	0.311
Supervisor encourages publishing†	4.555	4.346	4.536	4.461
Unmet expectations about publishing*	0.196	0.250	0.185	0.241
Teaching activity*	0.384	0.350	0.334	0.259
Teaching training*	0.257	0.200	0.192	0.133
Unmet expectations about teaching*	0.170	0.303	0.261	0.292
Supervisor encourages collaboration†	4.261	4.101	4.330	4.244
Unmet expectations about collaboration*	0.089	0.131	0.108	0.122
Has a mentor*	0.842	0.728	0.766	0.778
Supervises others*	0.805	0.747	0.732	0.680
Publications	3.822	7.839	4.891	5.854
Submitted articles	3.434	8.026	4.082	5.192
Proceedings	1.465	3.989	2.086	2.466
Patents	0.111	0.163	0.151	0.184
Presentations	4.120	7.176	4.285	4.267
Ln(Salary)	10.863	10.841	10.831	10.812
Hours	49.332	47.441	47.465	48.948
Stress	3.087	2.962	2.868	2.903
Satisfaction†	3.967	3.755	3.823	3.872
Supervisor encourages work life balance†	3.807	3.783	3.833	3.714
Supervisor provides career advice†	3.920	3.680	3.873	3.857
Supervisor provides recognition†	4.223	4.050	4.330	4.227
Meet weekly or more with supervisor*	0.559	0.642	0.684	0.727
Had a formal performance evaluation*	0.455	0.512	0.465	0.491
Has a written work plan*	0.526	0.591	0.589	0.586
Work plan incorporates personal goals†	2.577	2.431	2.460	2.514
Supervisor encourages independence†	4.269	4.010	4.300	4.221
N. observations	1,619	168	611	1,267

* Dummy variable. † Ordinal variable on a scale of 1-5 (with the exception of "work plan…goals," which is 1-3).

Table 2: Networks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Found job through network		Found job through advertisement		Took job to work with specific person		Took job for prestige	
Temporary resident	-0.0455**	-0.0504	0.0657***	0.0636**	-0.0512***	-0.0473	0.0806***	0.0264
	(0.019)	(0.031)	(0.016)	(0.027)	(0.019)	(0.031)	(0.019)	(0.032)
Required to leave		0.00819		-0.0347		0.0749***		0.0533**
		(0.026)		(0.024)		(0.027)		(0.025)
English First Language		-0.0151		0.00985		0.0467*		-0.035
		(0.027)		(0.024)		(0.026)		(0.027)
Non-white		-0.0393*		0.0677***		-0.0601***		-0.0212
		(0.022)		(0.019)		(0.021)		(0.021)
N obs.	3665	3614	3665	3614	3593	3551	3598	3554

Note: OLS regressions with robust standard errors in parentheses. * significant at the 10% level. ** significant at the 5% level. *** significant at the 1% level. “Temporary resident” is a dummy equal to 1 if the survey respondent was not a US citizen or permanent resident at the time of the survey. Regressions in even numbered columns include controls listed in the table as well as controls for field and year, female gender, US citizens and permanent residents trained abroad, and years from PhD completion.

Table 3: Grants and Publishing

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Grants							
	Activities	Training	Supervisor encourages†	Less than expected	Activities	Training	Supervisor encourages†	Less than expected
Temporary resident	-0.148***	-0.0144	-0.287***	0.0995***	-0.0583*	-0.0158	-0.121	0.0526*
	(0.020)	(0.019)	(0.074)	(0.019)	(0.032)	(0.031)	(0.117)	(0.031)
Required to leave					-0.0488*	-0.0776***	-0.132	-0.015
					(0.026)	(0.027)	(0.098)	(0.028)
English FL					0.0433	-0.0612**	0.14	-0.0877***
					(0.029)	(0.027)	(0.104)	(0.026)
Non-white					-0.0718***	0.0339	-0.0145	-0.00107
					(0.022)	(0.022)	(0.080)	(0.021)
N	3637	3636	3589	3374	3597	3600	3554	3348
	Publishing							
	Activities	Training	Supervisor encourages†	Less than expected	Activities	Training	Supervisor encourages†	Less than expected
Temporary resident	0.0323**	0.0941***	-0.192**	0.0311*	0.0403*	-0.019	0.113	0.0317
	(0.015)	(0.017)	(0.092)	(0.016)	(0.022)	(0.028)	(0.149)	(0.025)
Required to leave					-0.0089	0.0307	-0.257**	0.0376*
					(0.019)	(0.025)	(0.126)	(0.023)
English FL					0.00324	-0.0763***	0.196	-0.000296
					(0.020)	(0.025)	(0.127)	(0.023)
Non-white					0.00101	0.123***	-0.0411	-0.0473***
					(0.017)	(0.020)	(0.101)	(0.018)
N	3653	3629	3590	3577	3603	3594	3557	3546

Note: All coefficients are from OLS regressions, with the exception of the regressions indicated by † which are ordered logit. * significant at the 10% level. Robust standard errors in parentheses. * significant at the 10% level. ** significant at the 5% level. *** significant at the 1% level. "Temporary resident" is a dummy equal to 1 if the survey respondent was not a US citizen or permanent resident at the time of the survey. "Activities" =1 if the respondent is engaged in grants (as a PI) or publishing, "Training" =1 if the respondent received training in grant proposals or publishing, "Less than expected" =1 if the respondent's involvement in grant proposals or publishing in their current position was less than they expected, "Supervisor encourages" = extent of agreement with the statement "supervisor encourages grant proposals/publishing," from 1 (strongly disagree) to 5 (strongly agree). Regressions in columns 5-8 include the controls listed in the table as well as controls for field and year, female gender, US citizens and permanent residents trained abroad, how the respondent found the current job, productivity (patents, proceedings, publications and submissions) and years from PhD completion.

Table 4: Teaching, Collaboration and Mentoring

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Teaching							
	Activities	Training	Less than expected	Took job to teach	Activities	Training	Less than expected	Took job to teach
Temporary resident	-0.112***	-0.0482***	0.107***	-0.102***	-0.0551*	-0.0182	0.0807**	-0.0788***
	(0.018)	(0.017)	(0.020)	(0.016)	(0.030)	(0.026)	(0.034)	(0.024)
Required to leave					-0.0634***	-0.023	-0.00563	-0.0156
					(0.024)	(0.022)	(0.029)	(0.020)
English FL					0.00451	0.0374	-0.0530*	-0.0045
					(0.028)	(0.024)	(0.031)	(0.022)
Non-white					-0.0286	0.0264	-0.0191	-0.0157
					(0.021)	(0.019)	(0.024)	(0.018)
N	3637	2333	3626	2708	3598	2333	2686	3592
	Collaboration							
	Supervisor encourages†	Less than expected	Supervisor encourages†	Less than expected	Has a mentor		Has supervised others	
Temporary resident	-0.00624	0.0208**	0.029	0.0152	-0.0751***	-0.0617**	-0.134***	-0.0447*
	(0.080)	(0.010)	(0.127)	(0.017)	(0.016)	(0.026)	(0.017)	(0.026)
Required to leave			-0.125	0.00536		-0.0293		-0.0463*
			(0.110)	(0.016)		(0.023)		(0.024)
English FL			-0.0217	-0.013		0.000115		0.0413*
			(0.110)	(0.015)		(0.025)		(0.023)
Non-white			0.0821	-0.0158		0.0251		-0.0817***
			(0.085)	(0.012)		(0.021)		(0.020)
N	3592	3648	3558	3597	3640	3612	3639	3599

Note: All coefficients are from OLS regressions, with the exception of the regressions indicated by † which are ordered logit. * significant at the 10% level. Robust standard errors in parentheses. * significant at the 10% level. ** significant at the 5% level. *** significant at the 1% level. "Temporary resident" is a dummy equal to 1 if the survey respondent was not a US citizen or permanent resident at the time of the survey. "Activities" =1 if the respondent is engaged in teaching, "Training" =1 if the respondent received training in teaching, "Less than expected" =1 if the respondent's involvement in teaching or collaboration in their current position was less than they expected, "Took job to teach" = 1 if respondent took their current position because it offered an opportunity to teach. "Supervisor encourages collaboration" = extent of agreement with the statement "supervisor encourages collaboration with other researchers," from 1 (strongly disagree) to 5 (strongly agree). "Has a mentor"= 1 if respondent has a mentor. "Has supervised others"= 1 if respondent has supervised others in the current position. Regressions in columns 5-8 of the top panel and columns 3, 4, 6, and 8 of the bottom panel include the controls listed in the table as well as controls for field and year, female gender, US citizens and permanent residents trained abroad, how the respondent found the current job, and years from PhD completion.

Table 5: Working conditions and Monitoring

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Ln(Salary)	Hours	Stress†	Satisfaction†	Work life†	Career Adv†	Recognition†	Frequency	Perf Eval	Work plan	Plan goals†	Indep. †
	Basic controls											
	Pay, hours, satisfaction, etc.							Monitoring				
Temporary Resident	-0.0585***	-0.817**	-0.315***	-0.174**	-0.0774	-0.0879	0.0852	0.128***	0.0167	0.0579***	-0.0774***	-0.0459
	(0.011)	(0.375)	(0.075)	(0.074)	(0.074)	(0.073)	(0.079)	(0.020)	(0.020)	(0.020)	(0.028)	(0.078)
N	3636	3047	3199	3645	3589	3586	3596	3622	3605	3606	2061	3591
	Full controls											
Temporary Resident	-0.00706	0.401	-0.283**	0.057	0.124	-0.0276	0.233*	0.0303	-0.0346	-0.0378	-0.0668	-0.0539
	(0.022)	(0.566)	(0.119)	(0.113)	(0.117)	(0.121)	(0.124)	(0.029)	(0.031)	(0.032)	(0.045)	(0.124)
Required to leave	-0.0216*	0.388	0.208*	0.0775	-0.194*	-0.0676	-0.193*	0.00506	-0.00884	0.0178	-0.0128	0.0124
	(0.013)	(0.497)	(0.109)	(0.100)	(0.103)	(0.103)	(0.113)	(0.025)	(0.027)	(0.027)	(0.039)	(0.106)
English FL	0.0553***	1.618***	0.180*	0.476***	0.206*	0.127	0.126	-0.0477*	-0.0534*	-0.0178	-0.000213	0.0822
	(0.020)	(0.505)	(0.106)	(0.097)	(0.107)	(0.107)	(0.109)	(0.026)	(0.028)	(0.028)	(0.041)	(0.109)
Non-white	-0.000922	-1.366***	-0.0671	0.036	0.113	0.124	0.180**	0.118***	0.0535**	0.174***	-0.0328	0.133
	(0.017)	(0.423)	(0.095)	(0.088)	(0.085)	(0.081)	(0.090)	(0.021)	(0.022)	(0.023)	(0.033)	(0.088)
N	3585	3026	3175	3608	3553	3551	3559	3570	3565	3566	2039	3554

Note: All coefficients are from OLS regressions, with the exception of the regressions indicated by † which are ordered logit. Robust standard errors in parentheses. * significant at the 10% level. ** significant at the 5% level. *** significant at the 1% level. "Temporary resident" is a dummy equal to 1 if the survey respondent was not a US citizen or permanent resident at the time of the survey. Regressions in the bottom panel include the controls listed in the table as well as controls for field and year, female gender, US citizens and permanent residents trained abroad, how the respondent found the current job, productivity (patents, proceedings, publications and submissions) and years from PhD completion. Variables indicated by † are ordinal variables. Stress= extent of stress in current position, Satisfaction = extent of satisfaction with current position, The following variables Career advice = supervisor provides career advice, Recognition = supervisor provides recognition, Work life = supervisor encourages work-life balance. Frequency = 1 if respondent meets with supervisor at least once per week. Perf Eval = 1 if respondent has had a performance evaluation. Work plan = 1 if respondent has a written work plan. Plan goals =1 if the work plan incorporates the respondent's personal goals. Indep = supervisor encourages independent research.

Table 6: Plans to leave the US

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Satisfaction	-0.0201**							-0.0230*	-0.0057
	(0.010)							(0.013)	(0.010)
Plan goals		-0.0549**						-0.0311	-0.036
		(0.022)						(0.023)	(0.013)
Recognition			-0.0286***					-0.0044	-0.0295**
			(0.009)					(0.020)	(0.013)
Collaboration				-0.0196**				-0.0157	0.0071
				(0.009)				(0.019)	(0.013)
Has a mentor					-0.0425*			-0.0537	-0.0315
					(0.023)			(0.034)	(0.028)
Training in teaching						-0.0473*		-0.0379	-0.0396
						(0.027)		(0.036)	(0.028)
Training on publishing							-0.0395*	-0.0282	-0.0304
							(0.021)	(0.028)	(0.022)
J-1 visa	0.1377***	0.1484***	0.1373***	0.1379***	0.1362***	0.1388***	0.1373***	0.1450***	0.1163***
	(0.020)	(0.025)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.026)	(0.023)
Years since PhD	-0.017***	-0.0098	-0.0173***	-0.0169***	-0.0172***	-0.0163***	-0.0166***	-0.0093	-0.0186***
	(0.006)	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)
English first language	0.031	0.0152	0.0285	0.0267	0.0265	0.0249	0.0229	0.0211	0.0253
	(0.032)	(0.041)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.041)	(0.032)
Non-white	-0.0214	0.0171	-0.0192	-0.0194	-0.0165	-0.0211	-0.0166	0.0212	-0.0068
	(0.021)	(0.028)	(0.021)	(0.021)	(0.021)	(0.021)	(0.022)	(0.029)	(0.022)
Female	0.0033	0.0106	0.0033	0.0053	0.0063	0.0087	0.004	0.0103	0.0055
	(0.021)	(0.029)	(0.021)	(0.022)	(0.021)	(0.021)	(0.021)	(0.029)	(0.022)
R squared	0.0932	0.1088	0.0967	0.0931	0.0925	0.0926	0.0921	0.1183	0.1039
N	1860	1106	1844	1840	1861	1850	1851	1090	1827

Note: All coefficients are from OLS regressions, with the dependent variable a dummy equal to 1 if the respondent reports planning to leave the US in the next 10 years. Only temporary residents are included in this regression. Robust standard errors in parentheses. * significant at the 10% level. ** significant at the 5% level. *** significant at the 1% level. The number of observations in column 8 is lower due to missing values in the "Plan goals" variable. In column 9, missing values of "plan goals" are filled in with zeroes and a dummy for observations with missing values is included. Regressions include the controls listed in the table as well as controls for field and year, female gender, US citizens and permanent residents trained abroad, how the respondent found the current job, productivity (patents, proceedings, publications and submissions) and years from PhD completion.