Permanent Visas and Temporary Jobs: Evidence from Postdoctoral Participation of Foreign PhDs in the U.S.

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Abstract

About 75 percent of U.S.-trained, non-citizen PhDs in science and engineering work in the U.S. after graduation, and 54 percent of those who stay take postdoctoral positions. The probability of postdoctoral participation is substantially higher for temporary visa holders than for permanent visa holders because of visa-related restrictions in the U.S. labor market. To identify the causal effects of visa status on entry into a postdoctoral position, this paper uses a unique shock to visa status generated by the Chinese Student Protection Act of 1992. Eligibility for the act is used as an instrumental variable for visa status. 2SLS estimates show that permanent visa holders are 24 percent less likely to take postdoctoral positions than temporary visa holders. The effects of a permanent visa vary considerably across research fields, but for most fields, it reduces postdoctoral participation significantly.

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INTRODUCTION

The prevalence of low-paid postdoctoral positions among recent PhDs in science and engineering (S&E) has attracted much attention (NSB, 2008). From 1985 to 2006, postdocs employed in U.S. academia almost tripled, from 8,700 to 23,400, while full-time faculty positions only increased by 26 percent (NSB, 2008).[2] A temporary postdoctoral position has become the most popular postgraduate plan among new PhDs in the U.S. In 2005, 55 percent of all new PhDs in S&E took a postdoctoral position, rising from 46 percent in 1985 (NSF, 2005). At the same time, the wage gap between postdocs and non-postdocs among new PhDs increased: The annual mean salary of postdocs relative to that of non-postdocs decreased from 63 percent in 1993 to 53 percent in 2001 (NSF, 2001).

The high number of postdoctoral positions and the low wages paid to postdocs suggest that the supply of postdocs has increased. This increase has coincided with the increasing number of foreign PhDs trained in American universities. During the same time period, the percentage of non-citizens among new PhDs in S&E increased from 26 percent to 48 percent; 82 percent of these non-citizen PhDs held a temporary visa at graduation, and 75 percent remained in the U.S. after graduation (NSF, 2005).[3] Compared to citizens and permanent residents, foreign PhDs who hold a temporary visa are more likely to take a postdoctoral position, possibly reflecting more limited job opportunities due to work visa restrictions in the U.S. (Stephan & Ma, 2005).

It is difficult to identify the causal effects of visa policies on postdoctoral participation. Compared to citizens and permanent residents, temporary visa holders may have different social networks and communication skills, which may affect their postdoctoral participation. To deal with the endogeneity of visa status, I use a

[2] The number of postdocs reported here also includes those who obtained their PhD degree abroad.

[3] Freeman, Jin, and Shen (2004) and Bound, Turner, and Walsh (2009) report and analyze this trend in detail. Finn (2010) analyzes the stay rate of non-citizen PhDs in S&E in detail.

one-time and unexpected shock to visa status, which was generated by the Chinese Student Protection Act of 1992. The act was a response to the Tian'an Men Square Incident in 1989, and it unexpectedly granted thousands of Chinese nationals a permanent visa. I use eligibility for a permanent visa associated with the act as the instrumental variable to estimate the causal effects of visa status on postdoctoral participation, using data from the Survey of Earned Doctorates, a unique census of all PhDs trained in the U.S. The two-stage-least-square (2SLS) estimates show that permanent visa holders are 24 percent less likely to take postdoctoral positions than temporary visa holders. The effects of a permanent visa vary considerably across research fields, and they significantly reduce postdoctoral participation in most fields.

As a crucial part of the scientific workforce, the rapid growth of the postdoctoral population has caused much debate related to science policies.[4] To further the discussion, it is necessary to understand the reasons driving this growth. Freeman et al. (2001) describe the competition between research labs as a "tournament," in which Principal Investigators (PIs) must compete for research funds by publishing more work faster. With a limited budget, PIs have strong incentives to maintain a large research team with low costs, increasing the demand for postdocs. Stephan and Ma (2005) show that the increase of postdoctoral positions is also related to the decrease in the demand for PhDs in both public and private universities, measured by the decrease of total fund revenues.[5] Since most postdocs are funded by federal research funding, fluctuations in the funding also affect the demand for postdocs (Stephan,

[4] The postdoctoral population plays a substantial role in U.S. science and engineering research. Black and Stephan (2008) report that 87 percent of their surveyed papers in *Science* have either a current postdoc or a graduate student as one of the authors. Many PIs apply for grants based on research conducted by postdocs in their labs (Freeman et al., 2001). The work of postdocs also allows PIs to spend more time managing labs and competing for research funds (Decker et al., 2007). Meanwhile, postdocs routinely help train undergraduate, graduate, and medical students (NAS, 2000).

[5] Ehrenberg (2003) also points out that a main reason for the fast growth of non-tenure-track jobs in academia is that universities cannot afford the higher salaries for tenure-track faculty.

2008).[6] This paper adds to the literature by examining the supply side of the story. Particularly, I use visa restrictions to explain different patterns of postdoctoral participation between temporary visa holders and permanent residents, which cannot be explained by general changes in demand.

By using an exogenous shock in visa status, this paper also contributes to the debate on visa policies. For high-skilled immigrants, the current literature mainly focuses on the effect of visa policies on U.S. technological innovations. For example, Kerr and Lincoln (2010) show that fluctuations of the cap of H1B work visas affect the rate of Chinese and Indian patenting in the U.S. By comparing different visa types, Hunt (2011) shows that immigrants who enter the U.S. with a temporary student or work visa are more innovative than average natives, due to their higher education and field of study. As for the effects of visa status on outcomes in the labor market, the current discussion has been focused on low-skilled immigrants. For example, by using amnesty granted by the 1986 Immigration Reform and Control Act, Kossoudji and Cobb-Clark (2002) show that obtaining a legal permanent visa increases the wage of illegal immigrants by 6 percent, and this wage growth is closely related to job mobility. This paper links these two branches of research by showing that visa status also affects job choice among high-skilled immigrants. By providing more opportunities other than low-paid temporary postdoctoral positions, a permanent visa could also immediately increase their income.

POSTDOCTORAL PARTICIPATION AND VISA POLICIES

Postdoctoral participation varies across research fields and over time, explained by different characteristics of these fields and changing labor market conditions over time. These factors, however, cannot explain the variation among those who graduate in the same year and same field, but hold different types of visas. Among non-citizen PhDs who graduated from 1996 to 2005 and stayed in the U.S., Table 1 shows that

[6] From 1991 to 2000, 80 percent of postdocs worked in academia and 75 percent of them were supported by federal research funding (NSF, 2005).

temporary visa holders were much more likely to take a postdoctoral position than permanent visa holders in every field. For example, in the field of chemistry, the probability of taking a postdoctoral position was 26 percentage points higher for temporary visa holders. Even in the field of biology, where postdoctoral training is standard, the probability was 10 percentage points higher for temporary visa holders.

[Insert Table 1 Here]

The difference in postdoctoral participation could be explained by the fewer employment opportunities for temporary visa holders in the U.S. due to visa restrictions. To work in the U.S., temporary visa holders must have an H1B working visa and confront several constraints imposed by the visa.[7] First, temporary visa holders must find a job within 14 months of the expiration of their student visas, or else they lose their legal status in the U.S.[8] Second, many companies, government agencies, and high-security labs and programs only employ citizens or permanent visa holders and do not sponsor H1B visas (NRC, 2005). Third, the Department of Labor requires that employers pay their H1B employees at least as high as that paid to other employees for the same type of job. The extra cost involved in applying for a H1B visa may further discourage employers, particularly small companies, from employing temporary visa holders. Fourth, the H1B visa is tied to the employer, making job switch risky and costly. Lastly, H1B visa holders are not allowed to start their own businesses in the U.S., and the spouse of an H1B visa holder, who holds an H4 visa, is not allowed employment.

These visa restrictions are usually more relaxed for postdoctoral positions because postdocs are able to work with either a H1B work visa or a J1 visa for foreign scholars.

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[7] The H1B visa is specified for high-skilled immigrants who have a Bachelor's degree or its equivalent in their specialty field. The webpage of the U.S. Citizenship and Immigration Services provides more institutional details and restrictions of the H1B visa: http://1.usa.gov/8VIT7E.

[8] After graduation, they must apply for a 12-month certificate of Optional Practical Training (OPT) in order to work temporarily or look for employment. After the OPT expires, they have another 60-day grace period to stay in the U.S.

Thus, postdoctoral positions provide extra employment opportunities for temporary visa holders, but these positions may be less attractive for permanent residents as they offer very low wages. Among 1999 and 2000 graduates, 16 percent of postdocs who held a temporary visa reported that their primary reason for taking a postdoctoral position was "other jobs are not available," while the percentage among permanent visa holders was 12 percent (NSF, 2001).

Overall, a permanent visa expands job opportunities for temporary visa holders. If appropriate jobs are still not available, permanent visa holders can also choose to stay and continue looking for employment in the U.S., or they can become self-employed. A permanent visa also eliminates the institutional barriers involved in switching jobs. Without the risk of losing legal status in switching jobs, permanent visa holders have more bargaining power and are thus more likely to find a suitable job. As a result, postdoctoral positions may become less attractive to them.

DATA

To estimate the effects of visa status on postdoctoral participation, I need an individual-level data set on PhD recipients that includes visa status, job choices after graduation, research fields, and demographic variables. The Survey of Earned Doctorates (SED) is a unique individual-level census of doctorate recipients in U.S. institutions dating onwards from 1957. The survey includes detailed information on post-graduation employment status, such as postdoctoral or other employment, and job location in the U.S. or in other countries. Also recorded are visa statuses at the time of graduation, country of citizenship, research fields, and a number of demographic variables (such as gender and marital status). As the survey is a part of the graduation process, response rates are high, at around 92 percent. The data are maintained by the National Science Foundation, and the micro data are accessible with the use of a restricted license.

The sample used in this paper consists of Chinese and Indian students who received

their degrees between 1994 and 2000 in S&E, aged 27 to 35 at the time of degree receipt.[9] I restrict the duration of PhD study to 4 to 7 years, a typical time frame and one that accounts for 86 percent of the sample.[10] I use this sample for two reasons. First, the selected period covers an exogenous shock to visa status generated by the Chinese Student Protection Act (discussed in more details below), which I use to identify the causal effects of visa status. Second, 97 percent of Chinese and 93 percent of Indians in the sample plan to stay in the U.S. after graduation. Thus, their postdoctoral participation is mainly affected by the common factors in the U.S. labor market. The inclusion of Indian students augments the identification of fixed effects of different research fields or general effects over time, such as field-specific job market characteristics or changes in the U.S. economy.

Table 2 summarizes the sample. PhDs from China and India are most likely to stay in the U.S. after graduation: 97 percent of the Chinese PhDs and 93 percent of the Indian PhDs stay in the U.S. (only 58 percent of PhDs from all other countries stay). Therefore, Chinese and Indians are the most likely to be influenced by changes in visa policies. Chinese PhD recipients are also more likely to be female, older, married, and have more children than their Indian counterparts. Chinese PhDs concentrate primarily in biology and chemistry and Indian PhDs in engineering and computer science. As the fields of biology and chemistry have many more postdoctoral positions than engineering and computer science, the average percentage of postdoctoral participation among Chinese, 56 percent, is higher than that among

[9] Chinese and Indians are included if they were citizens in either country at the time of receiving their PhD degrees. I only include individuals who attended high schools and colleges in their home country, because studying abroad earlier may imply some special family backgrounds. To be representative, each selected age group must account for at least 5 percent of the sample.

[10] Twelve percent of the sample have missing information in the constructed *duration variable*. I assume that they are in the interval of 4 to 7 years because this interval covers 74 percent of non-missing observations. Dropping the missing observations from the sample only slightly changes the following estimation results.

Indians, 40 percent.[11]

[Insert Table 2 Here]

IDENTIFICATION

The basic empirical specification considers the probability of accepting a postdoctoral position as a function of visa status and covariates including indicators for research fields, graduation years, and demographic variables. The prediction is that the coefficient associated with visa status, a dummy variable equal to 1 for permanent visa holders, is negative. The difficulty associated with an OLS estimate is that differences in visa status among individuals are unlikely to be exogenous. As a result, OLS estimation does not produce a causal effect of visa status on postdoctoral participation.

The Endogeneity of Visa Status

The best way to address the concern about the endogeneity of visa status is to answer two questions: Why do some students have a permanent visa? Do their reasons for holding a permanent visa also affect their postdoctoral participation?

Permanent visas (also called Legal Permanent Residence visas or "Green Cards")

[11] In my sample, 5.7 percent of PhDs do not report their employment outcome. These missing values seem to distribute randomly across demographic variables, graduation years, and research fields. Particularly, the probability of missing employment outcomes is not related to visa status. Thus, I drop these missing values. I do not differentiate between "definitely taking a postdoctoral position" and "planning to take a postdoctoral position" for now, and Table 6 repeats my estimation by using only those who report "definitely taking a postdoctoral position." It seems more accurate to combine the two categories together to measure postdoctoral participation immediately after receiving a PhD degree. In the Survey of Doctoral Recipients (another survey from the NSF on PhDs in S&E who trained in the U.S. and remained in the country after graduation), 45 percent of PhDs who graduated between 2001 and 2005 had completed or were participating in postdoctoral appointment in 2006 (NSF, 2008). This number is the same as the percentage of those who stayed in the country and were "definitely taking a postdoctoral position" or "planning to take a postdoctoral position" in the SED from 2001 to 2005, but it is much larger than the percentage of those "definitely taking a postdoctoral position," 37 percent.

consist of two main types: employment based and not employment based.[12] If some PhDs hold a permanent visa because they have been formally employed in the U.S. before receiving their PhD degree, their work experiences, which are unobserved in the data, could affect their job choices and confound the effects of visa status. Holders of permanent visas that are not employment based, which include investment immigrants, humanitarian immigrants (refugees, asylees, and parolees), close relatives of U.S. citizens, and winners of the Diversity Lottery, could also differ from temporary visa holders in their postdoctoral participation.

For PhDs who have a permanent visa through investment, a rich family may affect their postdoctoral participation.[13] For PhDs who hold permanent visas as "humanitarian immigrants" or "close relatives of U.S. citizens," some unusual experiences in their home country or social networks in the U.S. could affect their job choices in ways different from temporary visa holders.[14] Political refugees may not be able to return to their home country after graduation, so their job choices could differ from those who have that option. Close relatives of U.S. citizens may have more job market information and social resources in the U.S., which can also alter job choices. Chinese (mainland) and Indians are not eligible for the Diversity Lottery, because they come from "high admission countries" and their participation therefore conflicts with the principle of *diversity*.

The Chinese Student Protection Act of 1992

[12] For more institutional details of obtaining a green card, see the webpage of the U.S. Citizenship and Immigration Service: http://www.uscis.gov/greencard.

[13] Obtaining a permanent visa through investment (EB-5 visa) requires that the applicants invest at least $1 million and create at least 10 jobs in the U.S., or invest half of a million dollars in areas with a high unemployment rate. This type of visa is family-based; thus, some PhDs could obtain this type of visa from their family members.

[14] There is a large literature on the value of network in the U.S. for immigrants. For example, Munshi (2003) finds that those Mexican immigrants who have larger networks in the U.S. are more likely to find a higher paying job.

The Chinese Student Protection Act of 1992 (CSPA) generated one-time, substantial, and unanticipated exogenous variation in visa status. In order to protect Chinese students and scholars from possible political persecution following the Tian'an Men Square Incident in June of 1989, the act allowed Chinese nationals who were in the U.S. sometime between June 5, 1989 and April 11, 1990, and their qualified family members, regardless of their locations during that time, to adjust their temporary visas to permanent visas.

The act was unexpected to all its beneficiaries as it was not discussed and proposed until 1992, 2 years after the eligibility period. The act became effective on July 1, 1993 and substantially boosted the number of permanent visa holders among Chinese PhDs who received their degrees between 1994 and 2000 (Figure 1). During those 7 years, only 12 percent of Indians, but 45 percent of Chinese, held permanent visas, including 77 percent of Chinese in 1995. Other than this period, however, the percentages of permanent visa holders in the two groups were similar.

[Insert Figure 1 Here]

The Instrumental Variable

I use eligibility for the CSPA as an instrument for having a permanent visa and construct a binary eligibility variable based on the time of graduate school entry in the U.S. When PhD entry years are missing, I use years and locations of master's degrees to infer eligibility. The Data Appendix reports concrete assumptions on constructing the variable. Incomplete information on the exact entry time in the U.S. leaves the eligibility indefinite for 19 percent (1,871 out of 9,665) of all Chinese PhDs in the sample.

Table 3 summarizes the characteristics of Chinese PhDs by eligibility. It shows a strong relationship between CSPA eligibility and visa status. In the CSPA-eligible group, 91 percent are permanent visa holders, compared to 21 percent in the ineligible group.

[Insert Table 3 Here]

For CSPA eligibility to be a valid instrumental variable, it should not affect postdoctoral participation other than by changing visa status. The CSPA was not expected by those who were eligible, so there is no self-selection problem based on the anticipation of this policy change. Also, eligibility depends solely on presence in the U.S. in the 10 months following the Tian'an Men Square Incident, not on any other characteristics that could affect postdoctoral participation. Table 3 shows that those who are eligible are very similar to the ineligible Chinese students in terms of observed demographics, such as gender and marital status. Also, the sharp increase in permanent visa holders in the eligible group does not change the stay rate of Chinese students. In the eligible group, the stay rate is 98 percent, which is not significantly different from the stay rate of 97 percent in the ineligible.

Qian and Chu (2003), Bieler (2004), and Poston and Luo (2006) show that most beneficiaries of the act were not the students who had protested, and the Chinese government did not obstruct study abroad after the incident. This indicates that the beneficiaries were typical graduate students, not political refugees. However, the turmoil after the incident might have motivated some Chinese students who would have been otherwise not interested in scientific research to enter U.S. PhD programs, simply as a way to leave China. Had this been true, the incident would likely have changed the distribution of academic capacity and postdoctoral participation among Chinese PhDs. One way to measure the distribution of academic capacity is to use the rankings of PhD programs. Those graduating from top programs in their field may have higher academic capacity and be more likely to take a postdoctoral position than those not trained in top programs (Stephan & Ma, 2005). Table 3 shows the percentages of Chinese PhDs graduating from the top 20 programs in their research field: 27 percent for the eligible and 24 percent for the ineligible. Thus, it is likely that the incident did not significantly change the distribution of academic capacity among Chinese PhDs.

Another concern about this approach is that the sudden receipt of a permanent visa may have encouraged affected students to drop out of their PhD program in order to work, which could have changed the component of PhD recipients and also affected their postdoctoral participation. From the limited available data on PhD attrition rates in 22 main research universities (CGS, 2007), I find that this selection bias may be insignificant. The CSPA-eligible PhDs must have been in the U.S. prior to April 11, 1990, so 83 percent of them had been in their PhD programs for at least 4 years by the time they received the CSPA permanent visa, starting on July 1, 1993 (NSF, 2005). CGS (2007) shows that the PhD attrition rate in S&E after the 4th year was only about 4 percent in the 1990s, much lower than the 27 percent in the first 4 years. Thus, it is unlikely that senior PhD students dropped out of their program simply as a result of the exogenous visa change.

Table 3 also shows the probability of postdoctoral participation in each group, adjusted for graduation years.[15] In most fields, the probability of being a postdoc is significantly lower in the CSPA-eligible group, which shows a strong negative correlation between postdoctoral participation and a potential permanent visa. In general, CSPA eligibility reduces the postdoctoral participation by about 8 percentage points.

ESTIMATION

Visa Status and Postdoctoral Participation

I use the following linear probability model to estimate the general effect of visa status on the probability of taking a postdoctoral position across all research fields:

$$P_{icfy} = \beta_0 + \beta_1 V_{icfy} + \beta_2 X_{icfy} + \beta_3 C_c + \beta_4 Y_y + \beta_5 F_f + \beta_6 C_c * Y_y + \beta_7 C_c * F_f + \beta_8 F_f * Y_y + u_{icfy} . \quad (1)$$

[15] The probability of being a postdoc is calculated by a linear probability model with six year dummies, and the base group is 1994 graduates.

For a PhD i who is from country c and graduates in field f and year y, P_{icfy} is a binary variable that is 1 for taking a postdoctoral position and 0 for other jobs in the U.S.[16] V_{icfy} is an indicator of visa status that equals 1 for a permanent visa and 0 for a temporary visa, and F_f are dummies for the research fields. Because the returns to postdoctoral study may vary across fields and over time, F_f and its interaction with year dummies Y_y are also included. Because of the endogeneity of visa status, I use CSPA-eligibility indicator T_{icfy} as the instrumental variable for V_{icfy}.

[Insert Table 4 Here]

Table 4 shows the OLS and 2SLS estimation results. In columns (1) to (4), I restrict the data to Chinese PhDs. The 2SLS estimates suggest that having a permanent visa reduces the probability of taking a postdoctoral position by about 14 percentage points, which is 24 percent of the average probability, 0.57. Adding demographics (gender, marital status, and number of dependents) into the model only slightly changes the coefficients of visa status. The estimated effects of visa status are also similar across different samples: Columns (5) to (8) show that adding Indian students into the sample, which controls for field and year effects, only slightly changes the results. The last row reports the coefficients and t-statistics of CSPA eligibility in all first-stage regressions. All else equal, CSPA eligibility increases the probability of having a permanent visa by 0.66.

[Insert Table 5 Here]

The estimated effects of visa status vary across research fields because each field has specific characteristics, job market conditions, and returns to postdoctoral training. Table 5 reports the estimated field-specific effects of visa status using different samples: Columns 1 to 4 show results for only Chinese, and columns 5 to 8 show

[16] I exclude those who plan to leave the U.S., 4 percent of my sample. Among those who do not participate in postdoctoral training, 85 percent work in industry, 13 percent work in academia (including community colleges and other school systems), and 2 percent work in governments.

results for both Chinese and Indians. A permanent visa significantly reduces the probability of postdoctoral participation in the five largest fields that total 93 percent of the Chinese sample. In the field of biology, where postdoctoral training is standard, an exogenously granted permanent visa decreases the participation probability by 9 percentage points. In the fields of physics and math, the effect of a granted permanent visa is particularly strong compared to the mean probability. This effect could be related to the competition for academic jobs from physicists and mathematicians from the former USSR during this period. Besides a large inflow of renowned mathematicians and physicists after the collapse of the USSR, the percentage of PhD students from these countries in these two fields also drastically increased from 1.2 percent in 1990 to 7.6 percent in 1999 (NSF, 2005). Borjas and Doran (2011) show that young American mathematicians shift away from research fields overlapped with these Soviet immigrants. By the same logic, Chinese green card holders may also leave postdoctoral positions as a response to the intense competition in academia.[17]

The OLS Bias and Heterogeneous Effects of Visa Status

The OLS underestimates the coefficients of visa status in physics and math, and is not significantly different from the 2SLS in other fields.[18] The direction of the OLS bias is ambiguous because unobserved factors that help in obtaining a permanent visa could affect job choices in different ways. For example, unobserved working experiences in the U.S. before receiving a PhD degree could increase the probability of having a permanent visa, but it could decrease or increase the probability of taking a postdoctoral position. Work experiences could help find jobs in private industry and thereby reduce postdoctoral participation, in which case the OLS coefficients are

[17] I also compare distributions of 46 subfields in the fields of math and physics across PhDs from different countries. I find that these distributions are more similar between Chinese and Soviet immigrants, than between Americans and Soviet immigrants. This is not surprising because Chinese college education in science closely followed the model of the Soviet Union before its collapse.

[18] A simple Durbin-Wu-Hausman test suggests the difference between 2SLS and OLS is very significant in the field of physics (P-value=0.01) and less significant in math (P-value=0.12).

overestimated. However, people who left previous jobs and studied in PhD programs may strongly prefer academic careers, in which case the OLS coefficients are underestimated. Also, being married to a U.S. citizen may expand an individual's social network and reduce postdoctoral participation, but this type of marriage could also relate to some unobserved outstanding academic productivity which motivates further postdoctoral training.

Thus, assuming that the effect of visa status is the same for everyone is likely problematic, even within a single research field. However, 2SLS can still identify the Local Average Treatment Effect (LATE) (Imbens & Angrist, 1994) of visa status under the heterogeneous effect of a permanent visa: the effect on students who hold a permanent visa because they are CSPA eligible, but would not otherwise have had one.[19] In other words, it identifies the effect of a permanent visa on those whose visa status is actually changed by visa-related policies, which has strong policy implications. The estimated LATEs suggest that, for temporary visa holders staying in the U.S. who are easily affected by visa policies and who accounted for 68 percent of all non-citizen PhDs in S&E from 2000 to 2005, visa policies could play a significant role in affecting postdoctoral participation.

A key assumption behind the LATE is the monotonicity of visa status with respect to the instrumental variable change. The assumption requires that when CSPA eligibility shifts from "ineligible" to "eligible," a subset of the population will be shifted from temporary visa holders to permanent visa holders, but no one shifts out. This is true because a permanent visa is *permanent* unless the holder violates immigration laws and regulations or commits a serious crime and becomes deportable.

[19] All results reported in Table 5 are similar without controlling for demographic variables. These field-specific regressions without demographic controls are all saturated in covariates (year dummies, a country dummy, and their interactions); thus, the 2SLS estimate is a weighted average of LATEs across covariate cells (Angrist & Imbens, 1995).

Robustness Check

[Insert Table 6 Here]

Table 6 reports various robustness checks. Due to the timing of CSPA-eligibility, PhDs who are eligible for the CSPA may stay in their programs for a longer time than those who are ineligible and receive their degrees in the same year. This long duration could also affect postdoctoral participation. The previous estimations restrict the PhD study duration to 4 to 7 years, a representative time that accounts for 86 percent of all PhDs. Panel A of Table 6 reports the estimation results among all PhDs regardless of the duration of PhD study. Particularly, I also control for years of PhD study. The results are essentially the same as in Table 4. The number of years spent in a PhD program reduces the probability of taking a postdoctoral position, but the effect is very small.

When defining postdoctoral participation, the previous sections combine definitely taking a postdoctoral position and planning to take a postdoctoral position.[20] Panel B focuses on those who have made job commitments (postdocs or non-postdocs) when surveyed, which again generates similar estimates as in Table 4: A permanent visa reduces the probability of taking a postdoctoral position by about 12 percentage points.

Another concern is that only including Indian students may not fully capture the general changes across fields and over years. To further augment the identification of these fixed effects, Panel C includes more foreign PhDs from the other eight largest source countries.[21] Together with Chinese and Indians, these students accounted for

[20] The SED is conducted in March and April every year, when some PhD recipients have not yet made a job commitment.

[21] These eight countries include Taiwan, Korea, Canada, Germany, Turkey, Brazil, Mexico, and Thailand.

70 percent of all non-citizen PhDs who stayed in the U.S. over the sample period. Still, both the OLS and the 2SLS results are similar to Table 4. The OLS estimate, in particular, is almost identical to the estimate that uses the Chinese sample only, which suggests that the magnitude of difference in postdoctoral participation between temporary and permanent visa holders is similar among non-Chinese immigrants.

POLICY IMPLICATIONS

The prevalence of postdocs has become a major issue in science policy, and visa policies for high-skilled immigrants have been debated for years.[22] This paper links these two policies and demonstrates that removal of visa restrictions could reduce the supply of postdocs. Although the CSPA was only applicable to Chinese PhDs in the 1990s, the visa restrictions apply to most immigrants and could affect postdoctoral participation among other immigrants who intend to work in the U.S. From 2000 to 2005, the probability of taking a postdoctoral position was 0.56 among non-Chinese temporary immigrants, whereas the probability was only 0.45 among non-Chinese permanent residents (NSF, 2005).

Removal of visa restrictions could affect the wages of both temporary immigrants and natives. Because the wage of postdocs is only about half the wage of non-postdocs, income increases for those who have a green card and leave postdoctoral positions. Lan (2011) shows that the smaller number of temporary immigrants and the reduced supply of postdocs increases the wage of native postdocs, without affecting the wage of native non-postdocs. Also, the increased wage of postdocs does not affect postdoctoral participation among natives.[23]

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[22] NSB (2008) emphasizes the importance of understanding the growth of postdocs in science policy. The most recent visa policy debate involved the hearing of the House on October 5, 2011, which focused on reforming the immigration system to encourage foreigners who earned advanced degrees in American universities to stay in the U.S. and contribute to technological innovation. Anderson (2011) proposes some specific policy adjustments to facilitate high-skilled immigrants to obtain a permanent visa.

[23] Freeman (2005) also reports that the postdoctoral participation of native PhDs is

By affecting the labor market, removal of visa restrictions could have multiple effects on scientific research. First, fewer U.S.-trained PhDs would take a postdoctoral position given the low wages, thus raising the wage of postdocs and the cost of research for PIs. Given a limited budget, PIs could hire more foreign-trained PhDs. Since there is little data about foreign postdocs in the U.S. who obtained their PhD degrees abroad, the size of this population and their productivity remain unclear.[24] Second, by opening more job opportunities and improving job mobility, removal of visa restrictions could encourage more foreign PhDs to stay in the U.S. and contribute to scientific innovation.[25] From 2000 to 2005, 77 percent of U.S. trained S&E PhDs who held a temporary visa stayed in the country, compared to 96 percent of permanent visa holders (NSF, 2005). Those who leave the U.S. when their visa expires may also have lower research productivity because of losing access to a good research environment, especially leaving for a developing country (Kahn & MacGarvie, 2012). Third, removal of visa restrictions could encourage foreign PhDs to work in non-academic sectors, which could accelerate knowledge diffusion and enhance cooperation between universities and other sectors (Thune, 2009; Zucker, Darby, & Torero, 2002). It could also facilitate foreign PhDs starting their own businesses, generating both innovation and employment opportunities (Wadhwa et al., 2007).[26]

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inelastic. From 1995 to 2002, the numbers of native postdocs barely changed even though the budget of the NIH doubled.

[24] Based on different sources of data, Freeman (2005) estimates that about half of all postdocs who work in academia have non-U.S. PhD degrees. Garrison, Stith, and Gerbi (2005) report that growth in the postdoc population in the biomedical sciences mainly reflects the recruitment of foreign-trained PhDs.

[25] There is a large literature about the contributions of high-skilled immigrants. Some recent examples include Stephan and Levin (2001, 2007); Chellaraj, Maskus, and Mattoo (2005); Black and Stephan (2008); Kerr and Lincoln (2010); Hunt and Gauthier-Loiselle (2008); and Hunt (2011).

[26] They report that 25 percent of technology and engineering companies, created in the U.S. from 1995 to 2005, have at least one foreign-born key founder. About 27 percent of those foreign founders have a PhD degree, and 53 percent of them finished their highest degree in the U.S.

CONCLUSIONS

Among non-citizen PhDs in S&E, temporary visa holders are more likely to take a postdoctoral position in the U.S. than permanent visa holders because of the more limited job opportunities. The significant and exogenous visa status shock generated by the Chinese Student Protection Act of 1992 provides an opportunity to estimate the causal effects of visa status on postdoctoral participation. In general, a permanent visa decreases the probability of postdoctoral participation among temporary visa holders by 24 percent. In most research fields, a relaxed permanent visa regulation may substantially decrease the postdoctoral population.

To fully understand the market of postdocs, future research should collect more information on those who receive their PhD degrees from non-U.S. institutions. How many of them are working in the U.S.? Do they leave or stay in the country after their postdoctoral training? Are they more or less productive than U.S.-trained PhDs? These postdocs are mostly likely to hold a J-1 visa for exchange scholars. Compared to H1B visa holders, J-1 visa holders are unlikely to adjust their visa to a permanent visa, and they are required to return home when their visa expires. Such restrictions could also affect behavior and should be incorporated into the future discussion on visa policies.

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DATA APPENDIX: THE CSPA-ELIGIBILITY VARIABLE

The CSPA allowed eligible Chinese applicants who were in the U.S. sometime between June 5, 1989 and April 11, 1990 (referred to hereafter as "the CSPA-eligible period" in the following), and their qualified family members, regardless of their locations during the time, to adjust their visa status to a permanent visa. The act was passed on October 9, 1992, and the application period began on July 1, 1993 and ended on July 1, 1994. I construct a binary CSPA-eligibility variable for the selected 9,665 Chinese PhDs in S&E using the following steps:

1. Those who entered their PhD program before 1990 (exclusively) were eligible. This group includes 1,859 observations (19 percent of the sample), and 92 percent of them had a permanent visa. For those whose PhD study was never interrupted, staying out of the U.S. for 10 months (June 1989 to April 1990) without returning to their program at least once was unlikely. For those whose study was interrupted, I assume they did not stay out of the U.S. during the entire CSPA-eligible period.

2. When the information on PhD entry years is missing, I use institutions and years of

master's degrees. People who earned a master's degree in the U.S. before 1991 (inclusively) were eligible. This group includes 419 observations (4 percent of the sample), and 86 percent of them had a permanent visa. For reasons similar to those above, I assume that they did not stay out of the U.S. for the entire 10-month CSPA-eligible period during or after their study for a master's degree.

3. Those who entered their PhD programs after 1990 (exclusively) and who had not previously studied in the U.S. were ineligible. This group includes 4,982 observations (52 percent of the sample), and 21 percent of them had a permanent visa. Although it was unlikely that they were CSPA eligible, some people could have indirectly benefitted from the act if they were married and their spouse was in the U.S. during the CSPA-eligible period. I ignore this complexity for three reasons. First, constructing the ineligible group based on marital status leaves about 30 percent of the whole sample as the unknown eligibility group. Second, marital status at the time of degree receipt, recorded in the data, is not very useful to infer marital status during the CSPA-eligible period. Third, these indirect beneficiaries could be seen as other normal permanent visa holders who have close relatives in the U.S. and their permanent visas could be treated as endogenous.

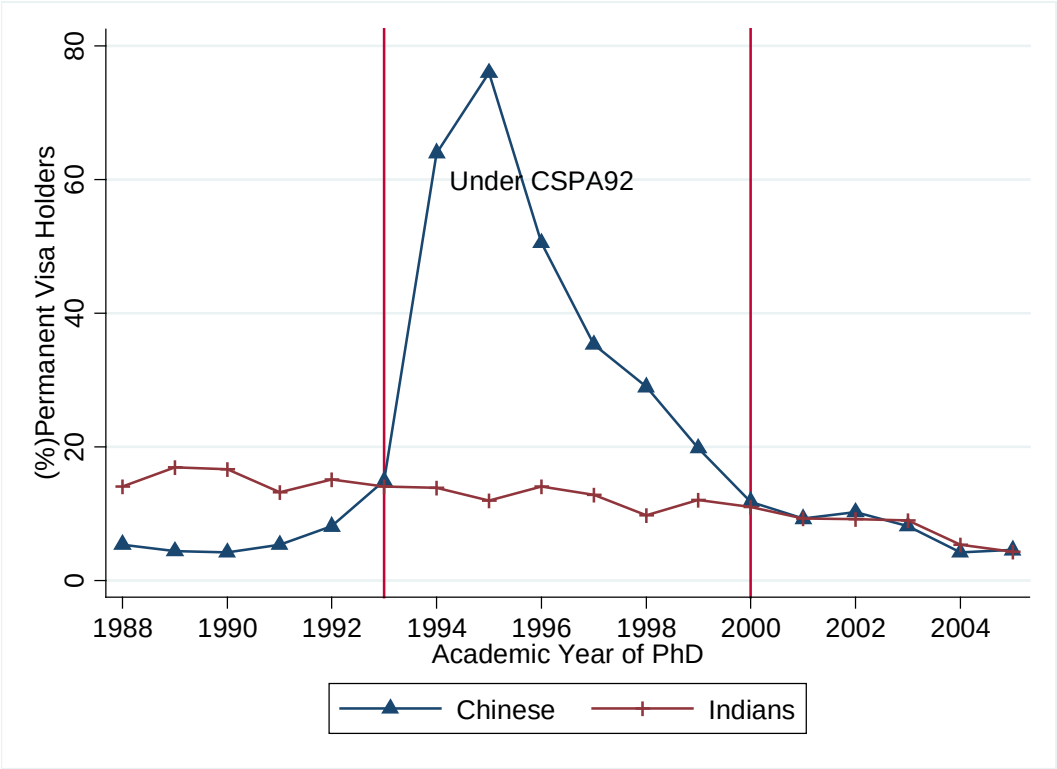
4. Those who entered their PhD programs in 1990, but received their bachelor's or master's degrees in other countries in the same year were ineligible. This group includes 534 observations (6 percent of the sample), and 19 percent of them had a permanent visa. Since most countries, especially China, award degrees in summer, those who entered the U.S. in 1990, but received degrees in the same year in other countries were unlikely to enter the U.S. before April 11, 1990, the last day of the CSPA-eligible period.

5. For those who entered their PhD programs in 1990, but received their bachelor's or master's degree in other countries before 1990, CSPA eligibility was unknown. This group includes 1,105 observations (11 percent of the sample), and 58 percent of them

had a permanent visa. Due to the turmoil after the Tian'an Men Square Incident in China, some Chinese students could have arrived in the U.S. at the beginning of 1990 and become eligible for the CSPA. Unfortunately, the SED did not record the PhD entry month then, so it was not possible to reliably infer the eligibility of this group.

6. For those who had no information in PhD entry year and no other useful entry information, CSPA eligibility was unknown. This group includes 766 observations (8 percent of the sample), and 52 percent of them had a permanent visa.

Figure 1: Chinese Student Protection Act of 1992 and Visa Status



***Source**: Author's tabulation. Survey of Earned Doctorates, National Science Foundation*

Table 1. Postdoctoral participation of non-citizens in S&E, 1996 to 2005.

Field	Probability of postdoctoral participation			
	Temporary visas (1)	Permanent visas (2)	Difference (3)=(1)-(2)	Number of observations
Agriculture and natural resources	.704	.493	.211***	2,302
Biology	.874	.771	.103***	13,744
Health science	.431	.303	.128***	2,105
Engineering	.335	.194	.140***	21,365
Computer science and IT	.209	.127	.082***	3,211
Mathematics	.443	.288	.155***	3,617
Physics and Astronomy	.674	.481	.194***	6,394
Chemistry	.707	.451	.256***	6,249
Total	.543	.451	.093***	58,987

******* $p<0.01$.

Source: Author's tabulation from the Survey of Earned Doctorate, National Science Foundation.

Table 2. Chinese and Indian PhDs in science and engineering receiving a PhD in FY1994 to FY2000, ages 27 to 35.

	Chinese	**Indians**
Number of observations	9,665	4,420
Permanent visas at graduation (%)	44	11
Staying in the U.S. (%)	97	93
Postdocs after graduation (%)	56	40
Age	32	30
Female (%)	29	21
Married (%)	82	52
Average number of dependents†	0.8	0.4

† "Dependents" does not include spouse and parents. It is a categorical variable with 3 indicating 3 or more dependents.

Source: Author's tabulation from the Survey of Earned Doctorate, National Science Foundation.

Table 3. Chinese students in science and engineering receiving a PhD in FY1994 to FY2000, ages 27 to35, by CSPA eligibility.

	CSPA eligible	Non-eligible
Number of observations	2,278	5,516
Permanent visas at graduation (%)	91	21
Staying in the U.S. (%)	98	97
Trained in top 20 programs (%)†	27	24
Age	31	31
Female (%)	29	29
Married (%)	80	83
Average number of dependents	0.8	0.8

Probability of postdoctoral participation, adjusted for graduation years††

	CSPA eligible	Non-eligible	Differences
Biology (2,538)	.922	.983	-.061**
Engineering (1,956)	.375	.451	-.076**
Chemistry (1,249)	.655	.791	-.136***
Physics and Astronomy (882)	.674	.889	-.215***
Mathematics (450)	.306	.441	-.135*
Agriculture and natural resources (191)	.782	.703	.079
Computer science and IT (172)	.125	.148	-.023
Health science (137)	.625	.520	.105
Total (7,575)	.625	.704	-.079***

*** p<0.01; ** p<0.05; * p<0.1.

† The ranking is based on the National Research Council (1995), except for agriculture and natural resources and health science. For agriculture and natural resources, I combine the top 10 programs in food science and soil science (the largest two subfields in the field) listed on this website: http://bit.ly/mFTT9b. For health science, I use the top 20 pharmacy programs (the largest subfield in the field) listed in the *U.S. News and World Report* 2009 ranking: http://bit.ly/HVN9I.

†† I calculate the postdoctoral percentages after controlling for six year dummies. The base group is 1994 graduates. I exclude those who plan to leave the U.S., making the sample size 3 percent smaller than the upper panel.

Source: Author's tabulation from the Survey of Earned Doctorate, National Science Foundation.

Table 4. OLS and 2SLS estimates of the effects of visa status on postdoctoral participation in S&E in the U.S.: Chinese and Indians receiving a PhD in FY1994 to 2000, age 27-35

	Postdoctoral participation of Chinese				**Postdoctoral participation of Chinese and Indians**			
Independent variables	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS	(7) OLS	(8) 2SLS
	(Mean probability of postdoc participation=.567)				(Mean probability of postdoc participation =.521)			
Perm visa	**-.117*** **	**-.139*** **	**-.113*** **	**-.135*** **	**-.116*** **	**-.134*** **	**-.112*** **	**-.132*** **
	(.011)	**(.025)**	**(.012)**	**(.025)**	**(.010)**	**(.025)**	**(.010)**	**(.025)**
Female			-.029***	-.026**			-.024***	-.022**
			(.011)	(.011)			(.009)	(.010)
Married			-.000	.001			-.010	-.008
			(.014)	(.014)			(.010)	(.010)
# of dependents			.015**	.015**			.012**	.012**
			(.006)	(.006)			(.006)	(.006)
Country effects	NO	NO	NO	NO	YES	YES	YES	YES
Constant	.862***	.878***	.902***	.917***	.658***	.660***	.689***	.689***
	(.103)	(.105)	(.097)	(.099)	(.101)	(.101)	(.098)	(.098)
Observations	7575	7575	7306	7306	11671	11671	11127	11127
R-squared	.319	.319	.322	.322	.316	.316	.317	.317
First stage coefficient (t statistics)		**.660*** ** **(44.8)**		**.666*** ** **(44.5)**		**.659*** ** **(44.9)**		**.666*** ** **(44.6)**

****** p<0.01, ** p<0.05*** ***Robust standard errors in parentheses***

Notes: The dependent variable is the binary postdoctoral participation indicator with 1 indicating postdoc status. The instrumental variable is the CSPA-eligibility indicator, described in the Data Appendix. All regressions include graduation year dummies, field dummies, and their interaction terms.

Source: Author's tabulation from the Survey of Earned Doctorates, National Science Foundation

Table 5. The effects of visa status on postdoctoral participation in each research field in S&E in the U.S.: Chinese and Indians, receiving a PhD in FY1994 to 2000, ages 27 to 35.

	Chinese only				Chinese and Indians			
	Mean probability (1)	OLS (2)	2SLS (3)	Observations (4)	Mean probability (5)	OLS (6)	2SLS (7)	Observations (8)
Engineering	.232	-.079***	-.105**	1,956	.255	-.079***	-.106**	3,958
		(.023)	(.045)			(.019)	(.045)	
Biology	.876	-.112***	-.091**	2,538	.877	-.105***	-.095**	3,257
		(.016)	(.039)			(.015)	(.039)	
Chemistry	.630	-.203***	-.186***	1,249	.646	-.210***	-.190***	1,592
		(.033)	(.072)			(.031)	(.072)	
Physics and astronomy	.549	-.097**	-.320***	882	.567	-.122***	-.320***	1,141
		(.042)	(.084)			(.039)	(.084)	
Mathematics	.273	-.054	-.203**	450	.274	-.065	-.204**	555
		(.055)	(.097)			(.050)	(.098)	
Computer Sci. and IT	.116	-.082	-.037	172	.130	-.121***	-.036	545
		(.057)	(.096)			(.030)	(.097)	
Health science	.489	-.008	.286	137	.380	-.052	.288	332
		(.106)	(.246)			(.074)	(.248)	
Agriculture and natural resources	.717	-.113	.045	191	.674	-.101	.023	291
		(.092)	(.165)			(.080)	(.167)	

*** p<0.01, ** p<0.05 Robust standard errors in parentheses

Notes: The dependent variable is the binary postdoctoral participation indicator with 1 indicating postdoc status. The instrumental variable is the CSPA-eligibility indicator. All regressions include a set of dummies for graduation years and 3 demographic variables: sex, marital status, and number of dependents. Columns 5 to 8 also include a country dummy and its interactions with year dummies.
Source: Author's Tabulation from the Survey of Earned Doctorates, National Science Foundation.

Table 6. Robustness check: OLS and 2SLS estimates of the effects of visa status on postdoctoral participation in S&E in the U.S. †

Panel A: Duration of PhD program between 3 to 8 years††		
	OLS	2SLS
Perm. visa	-.106***	-.147***
	(.010)	(.026)
PhD study duration	-.011***	-.009**
	(.003)	(.003)
Number of obs.	12,525	12,525
Panel B: Among those having made job commitments		
	OLS	2SLS
Perm. visa	-.097***	-.115***
	(.012)	(.030)
Number of obs.	7,425	7,425
Panel C: Foreign PhDs from the 10 largest source countries		
	OLS	2SLS
Perm. visa	-.114***	-.130***
	(.008)	(.025)
Number of obs.	18,471	18,471

*** p<0.01. Robust standard errors in parentheses

† All estimates use the same specification as used in columns (7) and (8) in Table 4.
†† The duration is truncated into the interval [3,8]: 3= 3 years or less; 8= 8 years or more.
Notes: Panels A and B include Chinese and Indians, controlling for demographic variables and dummies for year, country, fields, and their interactions. Panel C uses more countries with a similar specification.
Source: Author's Tabulation from the Survey of Earned Doctorates, National Science Foundation.