Chinese graduate students and US scientific productivity: evidence from chemistry*

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Abstract

Large numbers of Chinese-born students are graduating from US universities at the PhD level. The desirability of this phenomenon both from the perspective of the United States and of China is debated. In this paper, we show that graduate students with a Chinese name are more productive than other graduate students in the same department (chemistry) and university. We relate this finding to a more stringent selection process and to qualitative evidence suggesting that Chinese junior scholars spend more time in the lab. Our results suggest that Chinese graduate students are making a larger contribution towards US scientific productivity than previously thought and strengthen the case that the United States are benefiting from the influx of Chinese graduate students.

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1 Introduction

"The graduate student is the workhorse of the modern laboratory"

The Economist, 2007

Immigrants from China are a large, and increasing, fraction of Science and Engineering PhD graduates educated in the United States. The numbers are striking. Of 26'891 students graduating with a PhD degree in Science and Engineering in the United States in 2003, more than 2500 (9.2%) were born in China (NSF 2007). PhD students graduating in 2006 from US universities were more likely to have done their undergraduate studies at Tsinghua University or Peking University than at the University of California, Berkeley, or any other institution (Mervis 2008). The surge of Chinese students seeking tertiary education in the US can be explained by unprecedented population growth until the '70s and the increased investment in higher education in China. On the supply side, the relatively liberal Foreign Student Program has facilitated the entry of Chinese students in US educational institutions.

While one might expect a massive inflow of highly talented individuals to be beneficial for the United States (Freeman 2009), a number of counter-arguments have been raised. First, Chinese and other immigrants may crowd out US-born students from graduate programs, either because there is a limited number of spots available or by depressing wages of PhD-educated scientists and engineers (Borjas 2004, 2006). Second, graduate students typically do not bear the full cost of their training, so that the US are effectively subsidizing the tertiary education of foreign-born students (Borjas 2004). Finally, a number of security concerns have been raised.

The main contribution of the paper is to show that Chinese students graduating from US chemistry PhD programs write more and higher quality papers than other students during their thesis. This evidence is highly relevant for the assessment of the benefits for destination countries of admitting large number of foreign young with student visas. While it is already clear that the large demand for graduate positions in the US has helped universities to get staffed at lower costs, this new evidence on productivity can strengthen the arguments to keep the doors of the foreign student programs open. Moreover, there is a large heterogeneity in the quality of students coming from different countries, and the increasing primacy of Chinese students is clearly linked to the rising quality of training and of student selection in China. Cooperation with Chinese Universities might earn a preferential access to new talents, with obvious dynamic benefits that gets magnified by network externalities in the location choices of Chinese student.

The focus on Chinese students has two motivations. First, the recent flow of Chinese students to US universities is historically one of the most relevant episodes of skilled migration so far[1]. Second,

[1] A comparable, recent event of skilled immigration is the one from the former Soviet Union to Israel after 1989, documented in Paserman (2007)

Chinese students have the highest rate of stay after the end of their PhD program, thus representing "stable" inputs to the US stock of human capital[2]. As of 2000, 8.9% of doctorate holders in U.S. science and engineering occupations were born in China (NSF 07).

We use individual level data on the whole population of students completing a PhD program in over 200 chemistry departments. We identify the ethnic origin of these students by matching the data with an extensive list of Chinese family and first names. We show that Chinese students sort themselves unevenly across institutions, and this produces large differences in the proportion of Chinese PhDs even between universities in the same state. Productivity is measured by the number and quality of published research of these students until one year after completion of the PhD. For each university, we also collect data on all professors, using the same strategy to identify their ethnic origin. There is strong evidence that the Chinese students perform better, controlling for fixed unobserved and time varying observed characteristics of the programs they are enrolled in. Preliminary evidence shows that Chinese students' productivity advantage gets even greater if a Chinese professor supervises their research work. This might suggest either that Chinese professors are more capable of selecting the most talented PhD candidates, or/and that communication costs prevent Chinese students from fully expressing their research potential.

Two main explanations of the finding on the productivity of graduate students can be advanced. The first has to do with talent. Chinese students who manage to get a research position in a US lab are selected among an extremely large pool of potential applicants, as the numbers of highly educated Chinese get larger and selection in undergraduate admission gets tighter. The second explanation has to do with motivations. The Chinese faces higher opportunity costs when choosing the amount of effort to devote to research, as failure to publish reduces chances of getting postdoctoral positions and/or permanent Visas in the US. The considerable differential between US and China in terms of salaries for scientists and engineers employed may give a powerful economic incentive for Chinese graduate students to exert even more effort than their American counterparts. Interestingly, a survey from the Sigma Xi foundation found that Chinese post-docs spend more time than Americans in the laboratory (50.5 hours per week versus 49.8; Brumfiel 2005).

Our findings are related to a recent and growing literature on the role of foreign-born scientists and engineers in US Science. Hunt (2009) uses the National Survey of College Graduates to show that immigrants publish more scientific articles. Levin & Stephan (1999) show that individuals making exceptional contributions to Science and Engineering in the United States are disproportionately drawn from the foreign born. Kerr (2008b) matches inventors of USPTO patents residing in the US with a ethnic name database and finds an important share of inventors of Chinese and Indian ethnicity (13.9% over the period 2000-2004). Black and Stephan (forthcoming) use the same ethnic-name matching techniques for authors (based in the US) of *Science* papers and similar find

[2] According to estimates derived by Finn (2007) using Social Security data, the stay rate for Chinese doctorate recipients is around 92 percent after five years from the PhD, the highest observed for any country in 2005.

an important share of papers signed by authors with non-English and non-European names. An important advantage of our approach compared to the latter studies is that we observe not only success (publishing in a top journal, patenting,...) but also unsuccessful individuals.

Closest to our paper is the study of Stuen, Mobarak & Maskus (2007). Using a large dataset of publications over 1968-2003 and instruments for student enrollment, they find an effect of the number of doctoral students on productivity at the departmental level but no differential between US and foreign students.

The rest of the paper is organized as follows. Section II describes our data. Section III presents descriptive statistics on enrolment and productivity of Chinese graduate students. Results are in section IV. Section V discusses the problem of homonymity and how we address it. Section VI concludes.

2 Data

We build a list of PhD graduates in chemistry and chemical engineering using the Proquest Dissertations and Theses database. This database lists the name, title, graduation year, university and advisor of PhD graduates from major US universities. Considering the graduation years 1999-2008, we have a total of 32,069 individuals across all fields of chemistry (organic chemistry, biochemistry, analytical chemistry, chemical engineering, inorganic chemistry, nuclear chemistry, geochemistry). Comparisons with official figures from the National Science Foundation suggest that our coverage of chemistry graduates is excellent[3]. We do not observe students dropping out of the program or the time to graduation.

To construct individual productivity measures, we match our list of PhD graduates with publication data from Scopus. At the moment, we are considering only first-authored papers in constructing productivity[4]. In chemistry, first-authorship is the most prestigious spot[5] so that first-authored papers are a good proxy for productivity. We construct three measures of productivity: whether the graduate student has published any paper as first-author during his PhD[6], the number of papers first-authored and the same weighted by the 2008 impact factor of the publishing journal. Because we know not only the name and first initial of the PhD graduates but also their university and department, homonymity is not a major concern. We exclude from the sample graduate students who share the last name and first initial with another graduate student, or a professor, of his university

[3] NSF(09) reports that 29'308 students graduated with a PhD degree in chemistry, biochemistry, chemical engineering or geochemistry between 1999 and 2006 while the corresponding figure for our database is 28'765.

[4] Preliminary work, not reported here, shows that Chinese students have an higher productivity also when considering only non-first authored publications. This might indicate that not only they are individually productive, but they also participate effectively in the research work of other team members.

[5] In his book 'The Road to Stockholm', Istvan Hargittai reports (2002:231) that Martin Kamen had 'generously yield first authorship to Ruben since he badly needed it for promotion' and this could have been a factor in Kamen not receiving the Nobel prize for his discovery of carbon-14.

[6] We take publications form three years before the graduation year to one year after the graduation year.

and department. This results in a loss of less than 3% of observations. As explained *infra*, we conduct a number of robustness checks to verify that our results are not due to Chinese graduates students having frequent last names.

Unfortunately, we do not have information on citizenship or place of birth for PhD graduates. Instead, we identify Chinese students through a list of common Chinese surnames. This approach of ethnic name matching, introduced by William Kerr (2008) in his study of co-ethnicity in patent citations, has distinct disadvantages. Specifically we cannot distinguish between first- and second generation immigrants or between students originating from mainland China and Taiwan. However, large-scale Chinese immigration to the US is a relatively recent phenomenon so that we are confident that the vast majority of individuals we identify as Chinese through our name matching techniques are indeed born in China[7]. On the other hand, ethnic name matching enables us to analyze large data sets from publicly available sources. It is difficult to envision an alternative that would allow for the construction of individual productivity measures for such a large sample.

We might incur in two types of errors when identifying ethnicity through name lists. The first type of error concerns those students who have a chinese name according to our lists of first and last names, but in reality are not Chinese. This is most likely due to the commonalities between chinese names and names from Taiwan, Singapore, Hong Kong and Korea. The second type of errors concerns those students who are indeed Chinese, but fail to be identified as Chinese as they have a name or first name that is too rare to be included in the list. The Chinese migrants who change their first name with an occidental one are also at the origin of this second type of error. We use a subsample of universities where we have detailed biographic information for all PhD candidates to check to what extent our ethnic identification technique suffers from the two types of errors. At the top of table 1, it is shown that 90.21% of those identified as Chinese from our name list are indeed Chinese, as they did their undergraduate studies in China. Among the remaining 9.79%, 5.23% are likely to be Taiwanese, as they studied in Taiwan, and 3.49% are either descendants of Chinese migrants or migrated to the US for studies preceding the PhD. The second type of error is approximately of the same size: 91.19% of those educated in China are identified as Chinese through our name matching technique, while 8.81% failed to be identified as Chinese according to our lists.

[7] Since the passing of the Chinese Exclusion act in 1882 and until the late 1960s, the numbers of Chinese immigrants to the US were minimal. Until 1978, Chinese migration policy only allowed migration into socialist countries. The enactment of the Immigration and Nationality act in 1965 gave start to a period of steadily rising Chinese migration to the US. In 2002, of the more than 700 thousands temporary immigrants to the US from China, about one-tenth of them are students (USCIS data reported in Poston & Luo (2007))

Table 1 - Quality of name matching

	With Chinese name
Right Match	90.21% are educated in China
Wrong Match	9.79% not educated in China (5.23 Taiwan, 3.49 US)

	Educated in China
Right Match	91.19% have a Chinese name
Wrong Match	8.81% have not a Chinese name

3 Descriptive statistics

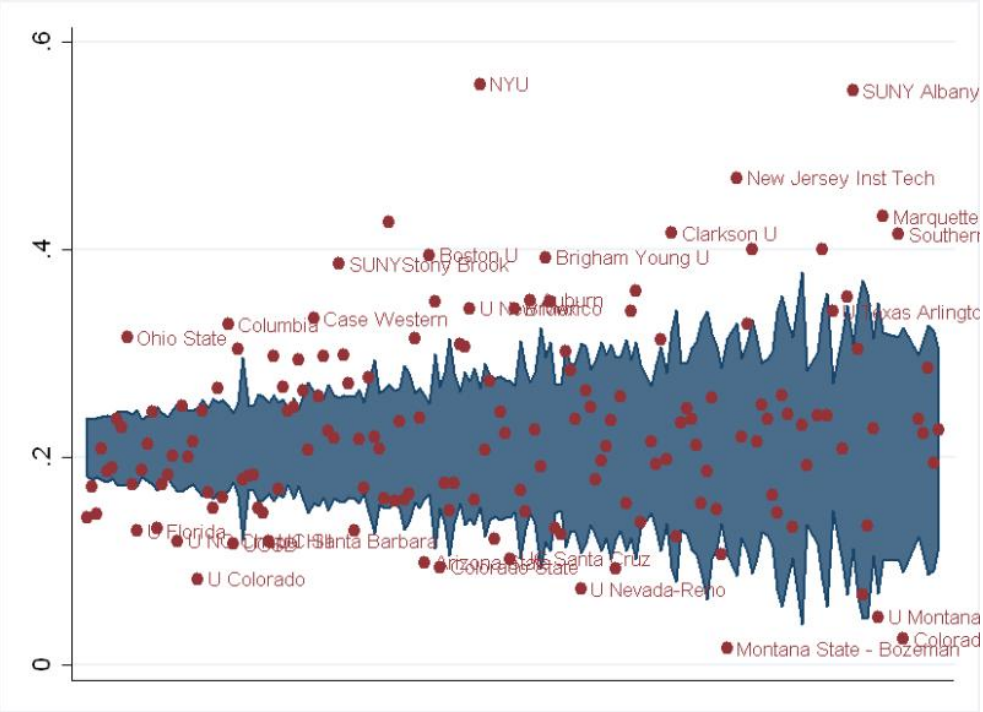
Out of 32,069 PhD graduates in chemistry, 4,413 or 13.76% have a Chinese last name. This fraction is more or less constant across graduation years. Chinese graduate students are not evenly split between universities. Instead, the fraction of Chinese students in the larger PhD program fluctuates from 8.2% (University of Colorado) to 55% (NYU).

To check whether a random allocation could have generated the observed dispersion of Chinese graduate students, we ran one thousand simulations whereby individuals were randomly assigned to universities taking into account university size[8]. From the simulated data, we can calculate a 95% confidence interval on the proportion of Chinese graduate students at each university[9]. We report these confidence intervals together with the observed allocations in figure 1.

[8] In each simulation, we had 35'000 graduate students of which 7'300 Chinese and 27'700 non-Chinese randomly allocated to universities according to their For instance, Stanford had 542 PhD graduates in chemistry during this period, or 1.54% of the total number of PhD graduates in chemistry. So in the simulation each of the 35'000 individuals had a 1.54% chance of being allocated to Stanford. For a specific simulation, we calculate the proportion of Chinese at each university

[9] the interval is constructed as the mean plus and minus 1.96 standard deviations of the simulated data so as to include 950 of the 1000 simulations

Figure 1. Fraction of PhD graduates in chemistry with a Chinese name by university



Dots represent the observed fraction of graduates with a Chinese last name. The area represents a 95% confidence intervals from a random allocation taking into account size. The confidence intervals were derived through 1000 simulations. Universities are ranked by their size (the number of PhDs graduating in chemistry). Larger universities are on the left.

Figure 1 provides evidence of ethnic sorting of Chinese across universities. We are currently investigating factors that might explain such ethnic sorting, with preliminary results suggesting a role for the proportion of ethnic faculty (faculty with a Chinese last name) and for the extent to which universities provide financial support to their graduates students.

Turning to productivity, Table 2 presents descriptive statistics on the scientific productivity of graduate students, distinguishing students with a Chinese last names and other students. The raw numbers suggest a productivity advantage for Chinese graduate students which we study in more detail in the next section.

Table 2 - Descriptive Statistics

	Chinese last name (n=4,404)				non-Chinese last name (n=27,656)			
Variable:	$\boldsymbol{\mu}$	$\boldsymbol{\sigma}$	**Min**	**Max**	$\boldsymbol{\mu}$	$\boldsymbol{\sigma}$	**Min**	**Max**
Any publications	0.280	0.449	0	1	0.232	0.422	0	1
# of publications	0.519	1.092	0	13	0.378	0.862	0	17
Weighted # of publications	2.867	6.158	0	72.637	2.148	5.038	0	75.033

Note: first-authored publications only. 1969 (5.6%) observations excluded due to homonymity

4 Estimation and results

We present our results using the number of first authored publications as productivity measure. We regress it on a dummy that take the value one for graduate students with a Chinese last and first name. We use university fixed effects to control for heterogeneity at the university-level and in particular differences in quality across universities. Subfield and year of graduation fixed effects are also included. The results are qualitatively the same using other measures of academic productivity (whether the graduate student has published any paper as first-author during his PhD, and the number of papers first-authored weighted by the 2008 impact factor of the publishing journal).

Table 3 - Results

	OLS	OLS	OLS
	(I)	(II)	(III)
	Number Pub	Number Pub	Number Pub
Chinese name	0.130***	0.0762***	0.120***
	[-0.015]	[-0.020]	[-0.015]
Late		0.264***	
		[-0.0231]	
Late*Chinese		0.113***	
		[-0.029]	
Advisor			0.162**
			[-0.0659]
Advisor*Chinese			0.225**
			[-0.104]
Total # of graduates	0.000611	0.00063	0.000613
	[-0.00054]	[-0.00054]	[-0.00054]
Total R&D expenditure	1.20E-06	1.37E-06	1.21E-06
	-2.38E-06	-2.38E-06	-2.37E-06
Constant	0.155***	0.159***	0.155***
	[-0.0376]	[-0.0376]	[-0.0376]
Graduation Year fixed effect	yes	yes	yes
Subfield fixed effect	yes	yes	yes
University fixed effect	yes	yes	yes
Observations	29034	29034	29034
R-squared	0.036	0.036	0.037

Notes: Robust standard errors in brackets.
* significant at 10%, **significant at 5%, *** significant at 1%

In all three regressions reported in columns I, II and III, we find that graduate students with a Chinese last name are more productive and the effects are significant at 1%. They are also quantitatively important: graduate students with a Chinese name are around 35% more productive considering the number of papers.

In column II, we examine whether the productivity advantage of Chinese has increased over time, adding the dummy late which refers to the graduation years after 2003. The productivity

of all PhD student has increased, but those of the Chinese relatively more, as evidenced by the interaction term. If we believe that the productivity advantage of Chinese is mainly due to the higher talent of those who make it until the PhD, the increase might be due either to an higher quality of later cohorts of chinese students demanding admission in US PhD programs. In turn, this quality improvement is linked to the higher number of people enrolled in higher education, especially from rural areas, and to the better quality of the education provided in China (Li et al, 2008). If we instead believe that the productivity advantage of Chinese has mainly to do with motivations, it is important to note that the proportion of Chinese students with a permanent visa has been decreasing[10]. Thus the pressure to publish to ensure a possibility to stay in the US through a Postdoc has become greater.

In column III, we introduce tentative evidence on whether Chinese students are more productive when collaborating with faculty of Chinese origin. We collected data linking students to advisors to address this point directly. As it can be seen, Chinese students' productivity benefit relatively more from the supervision of a Chinese Professors[11]. Again, two explanations can be raised. The first is that having a Chinese supervisor lowers communication and assimilation costs of Chinese students. The second is that Chinese Professors, through better networks and better knowledge of universities at origin, are able to select the better Chinese talents for their teams.

We already stated that one problem of our ethnic identification technique is the difficulty of distinguishing first from second generation migrants. We verify whether this issue is relevant for our results using the subsample of the data for which we dispose of biographic information.

[10] A substantial number of Chinese students were granted a permanent visa in 1992, through the Chinese Student Protection Act as a response to the Tian'an Men Square Incident in 1989.

[11] Chinese Professors are identified as those born or having done undergraduate studies in China. This is evidenced by the interaction term. A Chow test confirms the difference of the effect of a Chinese advisor for Chinese and non Chinese student (the test yields a value of 3.32, rejecting equality of coefficients at 10% level of significance).

Table 4. Estimation on biographic data

	OLS (I)	OLS (II)
	Number Pub	Number Pub
Chinese name	0.187***	
	-0.0339	
Undergraduate in China		0.179***
		-0.0344
Constant	0.221**	0.223**
	-0.0967	-0.0967
Controls (R&D and # of graduates)	yes	yes
Graduation year fixed effects	yes	yes
Subfield fixed effects	yes	yes
University fixed effects	yes	yes
Observations	6091	6091
R-squared	0.049	0.048

Notes: Robust standard errors in brackets.
* significant at 10%, **significant at 5%, *** significant at 1%

As shown by Table 4, we get very similar results if we either consider Chinese students as identified by our name matching techique, or Chinese students identified as those who did their undergraduate studies in China, thus excluding second generation migrants. This result confirms that distinguishing between first and second (or higher) generation migrants is not very relevant for the Chinese student case. It might also be interpreted as an indication that Chinese PhD students who followed undergraduate studies in US are not on average better than their connationals who migrated for the PhD.

5 Addressing homonymity

Because Chinese graduates students tend to have frequent last names, there is a concern that their greater productivity may in fact come from improper attribution of articles. In any large-scale matching between a list of scientists and a list of publications, mistakes arise because there is not enough information in the publication to be certain of the identity of the authors. The problem is more acute for common last names, hence the importance of the homonymity concern.

We address this both by using more information than is usually available for the match and by finding complementary evidence that is immune to homonymity concerns. On the first point, we match publications and people, not only by last name and first initial but also by university and department. Moreover we exclude from the sample graduate students that have the same last name, first initial, university and department as well as graduates students that have the same last name, first initial, university and department as a professor. Reducing the size of the sample in this leads to a loss of less than 3% of observations. The only remaining concern is that we do not have

a list of post-docs. Thus, we may mistakenly attribute publications first-authored by post-docs to graduate students with the same last name, first initial, university and department. Nevertheless, such mistakes must be few in number and are unlikely to affect the significance of the productivity results.

As a robustness check, we divide the sample into frequent last names/first initials combinations and less frequent combinations. To define frequent last names/first initials combinations, we consider the whole population of chemistry graduate students. It turns out that the coefficient on the Chinese dummy is not larger for the frequent combinations subsample than for the less frequent combinations subsample.

In a completely different approach that is not subject to homonymity concerns, we consider all publications from chemistry departments of US universities in our sample and match the names of the first authors with our list of common Chinese names. 23% of papers are signed by a first author who has a Chinese last name. However, only 21.7% of graduate students, 14% of post-docs[12] and around 6% of faculty have a Chinese last name. The 23% must thus come from higher productivity of scientists with a Chinese last name. Furthermore, the publications of first authors with a Chinese last name are published in journals with higher impact factor, which also holds in a regression with university fixed effects and year fixed effects. Finally, the publications of first authors with a Chinese last name receive more citations in a regression with university fixed effects, year fixed effects and publishing journal fixed effects.

6 Discussion and conclusion

The central result of this paper is that Chinese graduate students have a higher productivity on average than other graduate students in US universities. Two explanations suggest themselves: talent and motivation. Chinese graduate students are selected from a much broader pool of applicants. US education enjoys an excellent reputation in China and attracts the brightest and most motivated Chinese students. Moreover, once in graduate research, Chinese graduate student may experience higher pressure to succeed given that failure may result in a return to China with a much lower earning potential.

At present, we are searching for aggregate effects of the higher individual productivity of Chinese graduate students. We expect to find that universities with a higher fraction of Chinese among their graduate students have a higher aggregate productivity.

Our results on individual productivity have also led us to start investigating two related issues. The first is the determinants of ethnic sorting, i.e. the factors which explain higher concentration of Chinese students in certain universities. Preliminary results (not introduced here) suggest that

[12] Percentage based on Chinese citizens across all fields (Mervis, 2008) .

Chinese graduate students tend to co-locate with faculty of Chinese origin and that universities that have more generous policies in terms of support for graduate students attract more Chinese students. The second issue is the conditions under which Chinese students are more productive and in particular whether they are more productive when collaborating with faculty of Chinese origin. Preliminary evidence points to a positive effect of the ethnic link between the Chinese PhD student and his supervisor.

At a very micro level, our results imply that US chemistry departments that aspire to maximize their production of science should at the margin increase their intake of Chinese students. More important, however, is the relevance of our results to the debate on whether the US is benefiting from the influx of Chinese graduate students. To the extent that universities are selecting the best candidates for the PhD, US universities would have to accept lower quality applications in the absence of Chinese immigration. However, our results go further than this simple general equilibrium argument by showing that the Chinese graduate students that are studying in the US have a higher productivity than other graduate students. The contribution of Chinese-born junior scientists to US scientific productivity is larger than previously thought.

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