Chinese graduate students and US scientific productivity*

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Abstract

The migration of young Chinese scientists and engineers to undertake graduate studies in US universities is arguably one of the most important recent episodes of skilled migration. Using a new dataset covering around 16'000 PhD graduates in 161 US chemistry departments, we show that Chinese students have a scientific output during their thesis that is on average 25-30% higher than other students. In fact, conditional on acceptance into the same programs, Chinese students perform as well as the awardees of the NSF doctoral fellowship program- America's best and brightest in Science and Engineering. These results shed new light on the benefits of liberal student visa programs on destination countries.

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"Everyone here is smart but to succeed one needs to have a passion for science and they have it"

(A chemistry professor at MIT referring to the current generation of Chinese students.)

Immigrants from China are a large fraction of Science and Engineering PhD graduates educated in the United States. Of around 30'000 PhD students graduating in 2006, more than 4,300 (14.3%) were Chinese citizen (NSF 2009). Recent PhD graduates from US universities are 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). As of the 2000 census, 8.9% of doctorate holders in US Science and Engineering occupations were born in China (NSF 07).

Using a new dataset covering around 16'000 PhD graduates in 161 US chemistry departments, we show that Chinese students have a scientific output during their thesis that is on average 25-30% higher than other students. In fact, conditional on acceptance into the same programs, Chinese students perform as well as the awardees of the NSF doctoral fellowship program- America's best and brightest in Science and Engineering.

We relate the productivity differential between the Chinese and other students to a selection effect as obtaining admission into a US PhD program is relatively more difficult for Chinese students. Moreover, the majority of Chinese migrants come from a very restricted set of Chinese universities which are themselves extremely selective. However, we also advance as another potential explanation the fact that post-doctoral training and/or a career in the academia may be relatively more attractive to Chinese students.

Our results are highly relevant to the evaluation of the liberal US student visa program in terms of its welfare implications for the United States. They suggest that the immigration of Chinese student substantially expands the pool of talent available to the American scientific research entreprise, thus accelerating the rate of scientific progress and reinforcing the US comparative advantage in higher education. These advantages have, however, to be balanced against a number of possible counter-arguments, including the fact that migration of foreign graduate students may crowd out native students (Borjas 2004) or decrease incentives for natives to engage into scientific careers (Borjas 2006, Freeman 2009).

Earlier research on immigration and scientific productivity has focused on the role of foreign-born star scientists in US Science and on the propensity of natives and migrants to publish during their career. Levin & Stephan (1999) show that foreign-born US scientists are over-represented in the members of the National Academy of Science and the National Academy of Engineering, highly cited patents, highly cited scientists, citation classics, hot papers and founders of biotechnology firms. Hunt (2009) uses the 2003 Survey of College graduates to compare migrants and natives on a number of outcomes, including publishing. She finds that migrants who entered the US as graduate students publish more than natives but the differential is explained by highest degree and current occupation.

Our study is also related to the rich literature on self-selection, migration costs, and immigrants' performance in host countries (Borjas 1987, Chiquiar & Hanson 2005). Our results suggest that findings of a secular decline of immigrants' quality (Borjas 1987, Hatton & Williamson 2004) might not extend to student migration, as the increases in the pool of high quality candidates are tightening the competition for graduate positions. The relatively high quality of Chinese students migrating to the US is consistent with the theoretical conclusion of the Roy model on a positive link between self-selection and migration costs (as first shown in Borjas, 1987 and further discussed in Jasso & Rosenzweig, 1990). With respect to other immigrant groups, Chinese students might have to sustain relatively higher investments in their education to gain admission to top schools. Given that migration for graduates studies from China has surged only recently, networks reducing the costs and increasing the benefits of the migratory move (Carrington et al. 1996, McKenzie & Rapoport, forthcoming) might be still be relatively underdeveloped for Chinese students.

The paper is organized as follows. Section 1 provides background information on the migration of Chinese students, the NSF graduate research fellowship program and PhD degrees in chemistry. Section 2 describes the data construction and section 3 introduces descriptive statistics. The estimation and results are in section 4. Section 5 discusses potential explanations for the productivity advantage of Chinese students and section 6 concludes.

1 Background

1.1 Migration of Chinese students

The Immigration and Nationality Act of 1952 formalized the status of foreign students in US institutions by creating non-immigrant visa categories permitting temporary residence for study purposes (Bound et al. 2006). The F1 visa grants access to the US to students who are admitted by a recognized academic institution and can prove sufficient financial support. The number of student visas issued by the State Department climbed sharply from 65,000 in 1971 to 315,000 visas in 2000 (U.S. Department of State, Annual Report of the Visa Office, various years).

Until 1978, Chinese migration policy only allowed migration into socialist countries. The enactment of the Immigration and Nationality act gave start to a period of steadily rising Chinese migration to the US. In 2002, of the more than 700'000 temporary immigrants to the US from China, about one-tenth were students (USCIS data reported in Poston & Luo (2007)). Around 325'000 scientists and engineers based in the US in 2003 were born in China, Hong-Kong or Macau

(NSF 2007b), of which around three-fourth had obtained at least one university degree in the US (ibid.).

Since the end of the Cultural Revolution in 1977, China has made considerable investments in its higher education system, both in absolute terms and relative to other countries at similar levels of development[1]. From 1978 to 2006, the number of institutions of higher education more than tripled (Li, 2009) and enrollments increased even faster, growing at approximately 30% a year since 1999 (Li et al. 2008). In the 90's, Chinese universities graduated slightly less Bachelors in Science and Engineering than US universities but the number of Bachelors in S/E graduating from Chinese universities rose sharply in the 00s (cf figure 1).

(insert figure 1 about here)

Until recently, Chinese universities offered limited possibilities for graduate education[2]. Conversely, the leadership position of US universities as providers of high-quality doctoral education is undisputed. Chinese scientists and engineers report educational opportunities as the most important reason for coming to the United States (NSF 2007b).

1.2 The NSF graduate fellowship program

Although we are not interested in the National Science Foundation (NSF) graduate fellowship (GRF) program per se, we provide a brief of description as the NSF graduate fellows are a useful reference group for assessing the performance of Chinese students. The NSF graduate research fellowship is a highly prestigious award for Science and Engineering students. Freeman et al. (2005) refer to the program as 'Supporting the "Best and Brightest" in Science and Engineering'. Applicants to GRF program have to be either US citizen or permanent residents to be eligible. Around 1000 fellowships are awarded each year, which amounts to two fellowships per thousand Science and Engineering Bachelors. Applications are evaluated by panels based upon recommendation letters, graduate point average (GPA) obtained in undergraduate studies and quantitative and verbal graduate research examination (GRE) scores. The program provides financial support for three years of graduate study. While the dollar value of the stipend was relatively low in the 90's (at USD 15'000), the prestige of the award is considerable and could easily be leveraged to obtain the best possible financial support from host institutions, as universities actively woo NSF graduate fellows (WestEd 2002).

[1] Resource inputs have also been concentrated on a small number of elite institutions and in Science and Engineering departments in particular.

[2] Only slightly more than 1000 doctoral degrees in S/E were awarded in China in 1989 (NSF 2007a). The number of doctoral degrees in S/E awarded by Chinese universities reached 12'000 in 2003 (ibid), which was still only about one third of the the number of doctoral degrees in S/E awarded by US universities in the same year.

1.3 PhD degrees in chemistry

The median enrollment to graduation time in chemistry is six years (NSF 2006). In the first year of PhD graduate programs, students choose an advisor in whose lab they will conduct research, in principle for the rest of their PhD. Their publications will be almost invariably coauthored with the head of the lab. PhD students in chemistry are mainly supported by research assistantships (42.2%) and teaching assistantships (41.8%) while around 8% have fellowships (NSF 2007c). About half of graduating PhD students pursue careers in industry, either in the classical chemical industry or, increasingly, in the pharmaceutical industry. About 30% of chemistry PhD graduates pursue careers in the academia.

2 Data construction

We identify PhD students using Proquest Dissertations and Abstracts. This bibliographic database lists abstracts of completed PhD theses with the name of the student, the university and year of graduation as well as the field and the name of the advisor. It also includes links to the full-text of the theses, which is useful because theses from certain universities include additional bibliographical information on students (MacGarvie 2007).

Proquest Dissertations and Abstracts has the advantage of providing a good coverage of PhD graduates for US universities and recent years. However, it contains only limited information on students. In particular, we do not directly observe country of birth or of undergraduate education. Instead, we use a technique similar to that pioneered by Kerr (2008a, 2008b) in his study of ethnic patent inventors. This technique relies on the fact that names implicitly contains information about the origin of individuals and ethnicity can be reasonably well inferred by matching names to lists of ethnic names. Using the same approach, we constructed lists of Chinese last and first names and used them to code students as Chinese.

(insert table 1 about here)

To verify the quality of the results obtained with of our ethnic name matching algorithm we manually coded CVs for universities that require students to report biographic information in theses. The results, displayed in table 1, suggest that 88% of students coded as Chinese had received their undergraduate degrees in China (and a further 5% in Taiwan). Conversely, our algorithm identified 96% of students that did their undergraduate studies in China as Chinese.

We constructed scientific output measures by matching our list of students to publication data from Scopus. This bibliographic database has the advantage of including affiliation data for each author. To minimize errors in the matching process, we used the fact that most papers authored by chemistry students are written with their advisor as coauthor[3]. A publication is matched to a student if nine criteria are successfully met: The first author of the publication needs to have the (1) last name of the student (2) first initial of the student (3) correct departmental affiliation of the student (4) correct university affiliation of the student; and one of the coauthor on the paper had to have (5) the last name of the advisor (6) the first initial of the advisor (7) the correct departmental affiliation of the advisor and (8) the correct university affiliation of the advisor. Finally, the paper had to be published (9) no earlier than 3 years prior to the graduation of the student and no later than the year of graduation. Figure 2 in the appendix illustrates the matching criteria graphically.

3 Descriptive statistics

3.1 Location of Chinese students

We have a total of 16,073 students of which 2,385 (14.8%) are identified as Chinese. The share of Chinese students does not exhibit much variation over time but considerable variation across universities. NYU, Southern Illinois University and the University of New Mexico have more than 50% of Chinese students while Berkeley, the University of Colorado, Arizona State, the University of Oregon and the University of Texas at El Paso have less than 5%. The fraction of Chinese students is markedly higher in lower tier schools (schools with lower chemistry R&D budgets). Chinese students represent 10.2% of students in tier 1 schools, 13.2% in tier 2 schools, 16.3% in tier 3 schools and 20.6% in tier 4 schools.

(insert figure 3 about here)

3.2 Productivity

We focus on two measures of scientific output: first-authored publications and first-authored publications weighted by journal impact factors (thereafter: quality-adjusted first-authored publications). In chemistry, and in the physical and life sciences more generally, first-authorship is consistently assigned to the junior scholar who actually conducted the experiments and is thus particularly meaningful. Journal impact factors measure citations accumulated over two years by the average article published in a given journal. They are widely used to measure the quality and prestige of journals. We think of first-authored publications as the quantity of scientific output and first-authored publications weighted by journal impact factor as capturing both quantity and quality.

(insert table 2 about here)

[3] That is the case of 86% of publications in our sample

Table 2 displays means and standard deviations of the two scientific output measures for three groups of students: the Chinese students, the NSF fellows and all other students. NSF fellows have the highest mean on both measures while the the mean of the Chinese (a much larger group) is about halfway between the NSF fellows and all other students. Figures 4 and 5 are box-plots of the two scientific output measures for the three groups of students. In the figure 4, the distribution of the number of first-authored publications seems remarkably similar between Chinese students and NSF fellows. However, the distribution of first-authored papers by Chinese students has a greater mass at zero which cannot be seen in the box-plot. The median for the other students is at zero; slightly more than half of the other students have no first-authored publications which we relate to the fact that we do not count papers that are published after the year of graduation[4]. The distribution of quality-adjusted first-authored publications (figure 5) is similar except that NSF fellows have a higher median and 75th centile than the Chinese students.

(insert figures 4 and 5 about here)

4 Estimation and results

We regress scientific output, measured in terms of first-authored publications and first-authored publications adjusted for quality, on a dummy for Chinese students and a dummy for NSF fellows. We will estimate most regressions with a quasi-maximum likelihood conditional fixed-effects Poisson model (Hausman et al. 1984). This model has several desirable properties, including consistency of the coefficient estimates independently of any assumption on the conditional variance as long as the mean is correctly specified (Woolridge 1997) and consistency in the standard errors even if the data generating process is not Poisson. This estimator can also be used for fractional and non-negative variables (Santos Silva & Tenreyro 2006), such as quality-adjusted first-authored publications in our case. We implement this in Stata with the xtqmlp procedure written by Tim Simcoe[5].

(insert table 3 around here)

We first explore in table 3 differences in terms of first-authored publications among our three groups of students. The first column is a Poisson regression[6] with only year of graduation fixed effects and subject fixed effects[7]. The mean output of Chinese students is 23.9% (1-exp(-0.274)) higher than the output of other students while NSF fellows have a 36% productivity advantage. Once we introduce university fixed effects, the Chinese students have about the same productivity advantage as the NSF fellows (25.7% versus 28.6%). Thus, Chinese perform almost as well as

[4]We do not count papers published after the year of graduation because students change affiliation and we can no longer reliably match publications to students.

[5]available for download at scripts.mit.edu/ pazoulay/docs/xtqmlp.ado

[6]We use a Poisson with robust standard errors here because we have few fixed effects.

[7]These are subfields of chemistry (such as biochemistry, organic chemistry, etc.) as coded by Proquest Dissertations and Abstracts

NSF fellows enrolled in the same programs. Similar results are obtained with advisor fixed effects instead of university fixed effects (column 3)[8]. An attractive feature of this specification is that by comparing students who have the same advisor, we compare students who must be doing a very similar type of science. The results of this specification appear to rule out differences in the type of science conducted as a potential explanation for the productivity differential between the Chinese and other students.

(insert table 4 around here)

We then reproduce the same exercise with first-authored publications weighted by journal impact factors which adjust for the quality of the research. When we condition only on year of graduation fixed effects and subjects fixed effects, Chinese students have a 22.1% productivity advantage and NSF fellows have a 46.4% productivity advantage. Again, when we condition on same university or same advisor (column 2 and 3 respectively), Chinese students perform about as well as the NSF fellows. It is interesting to note that the Chinese coefficient is very similar across all specifications. This suggests that the productivity differential of Chinese students is not explained by school or advisor/team characteristics. On the other hand, the larger coefficient for NSF fellows in column 1 compared to column 2 and 3 can be associated with the fact that NSF fellows are located at better schools and work with better advisors than the average student.

We experimented with interacting the Chinese student dummy with school quality. The interaction of Chinese student with schools of lower quality is positive but not large or significant (results not reported here).

When comparing the Chinese to the NSF fellows, the interpretation of our results is complicated by the fact that higher ability students get admitted into better programs. However, better programs provide better advisors and resources which would result in higher output for students of similar ability[9]. The unconditional estimates of column 1 in table 3 and 4 overstate the advantage of NSF fellows over the Chinese students because they fail to take productivity-enhancing characteristics of programs into account. Conversely, the estimates conditional on graduation in the same programs (column 2 in table 3 and 4) ignore the fact that the school fixed effects partly reflect the average quality of students in each institution. However, even in the specification that is least advantageous to the Chinese students (table 4, column 1), their productivity advantage over other students is half of that of the NSF fellows. Overall, the performance of the Chinese students is remarkable considering that they are a much larger group.

[8] Note that with advisor fixed effects we lose a number of observations because some advisors have only one student in the dataset.

[9] In principle, the same type of reasoning applies to advisors: better students may be matched to better advisors but better advisors would result in higher output for students of similar ability. However, the coefficients are similar with school or advisor fixed effects so that within a school this complication is not relevant.

5 Discussion

Why do the Chinese perform so well? Our preferred explanation is a selection effect. US education enjoys an excellent reputation in China and attracts the brightest and most motivated Chinese students. Despite the fact that US universities are admitting large numbers of Chinese students, it is nevertheless considerably more difficult for a Chinese than for a native to obtain admission into a US PhD program. Evidence from Attieh and Attieh (1997) suggests that top US universities give substantial preference to US citizens in their admission decisions. While this may reflect an underlying preference for admitting natives, it could also be an optimal response to difficulties encountered in evaluating the applications of Chinese students (lack of familiarity with schools, grading systems and reference letter writers).

Precisely because of these difficulties, an undergraduate degree from one of the top Chinese university is a *de facto* requirement for entry into a US PhD program. Indeed Chinese graduate students overwhelmingly come from a set of extremely selective Chinese universities. Around 10 million high school finishers take the national college entrance exam but only three thousand are admitted into the two most prestigious schools, Peking University and Tsinghua University. Peking University and Tsinghua University are thus more selective than the most exclusive US institutions- the majority of MIT undergraduates would not have had standardized test scores high enough to be admitted into the undergraduate programs of Peking University and Tsinghua University[10].

Another potential explanation for the productivity effect is that a career in the academia and a post-doctoral training in particular may be relatively more attractive to Chinese students, thus increasing the incentives to publish during the PhD. In particular, immigration considerations may be relevant as maintaining valid visa status in the US is easier when undertaking post-doctoral training than working in industry[11]. Moreover, Chinese students may have an higher intrinsic taste for science or lack skills that are relatively more important in industry.

Stephan and Ma (2005) find a strong effect of temporary visa status on the likelihood of pursuing post-doctoral training. Moreover, among temporary visa holders, the Chinese have the highest likelihood to plan to stay in the United States and to remain in the field in which they graduate (Black & Stephan 2007). Taken together, these results suggest that Chinese have a higher propensity to pursue postdoctoral training. While this appears to support the notion that post-doctoral training is relatively more attractive to the Chinese, it is also consistent with the selection story if undertaking a post-doc is relatively more attractive for higher-ability students.

[10]The median maths SAT score of MIT undergraduates is 770 which is lower than the top centile cutoff. Only 3% of Chinese entrance test takers scoring in the top centile are admitted into Peking University and Tsinghua University.

[11]From the perspective of immigration law, post-doctoral training is not considered as work. Most post-doctoral fellows are on visitor (J1) rather than on work (H1B) visas. The latter, but not the former, are subject to a yearly cap.

Finally, ample anecdotal evidence suggests that Chinese graduate students work harder and spend more time in the laboratory[12]. It is clear, however, that effort is endogeneous with respect to both ability and the relative payoffs of future career options.

6 Concluding remarks

The contribution of this paper is to show that Chinese migrants perform very well in graduate studies in the United States, thus providing evidence that allowing universities to recruit graduate students from a broader pool of talent is an important benefit of liberal student visa programs. The graduate student is 'the workhorse of the modern laboratory' (The Economist 2007) and the migration of Chinese students enhances the productivity of US universities.

This benefit has to be balanced against potential negative effects, and in particular the fact that migration may decrease incentives for natives to engage in scientific careers (Borjas 2006). However, if the latter is a particular concern, policy instruments other than migration policy could be considered. For instance, fellowship programs that are explicitly targeted at US citizens and permanent residents, such as the NSF graduate research fellowships, might be expanded. Given that doctoral and post-doctoral stipends are about 1/6th of the lifetime income of scientists, raising the value of the stipend could have strong effects on career choices (Freeman et al., 2005).

Further research might investigate whether our findings extend to other disciplines where communication skills are more relevant. More importantly, our research does not address post-PhD outcomes. Graduate programs produce do not just produce science, they also produce scientists. To the extent that Chinese students are permanent additions to the US stock of human capital and Science & Engineering workforce, as seems to be the case[13], most of the gains for the US from the migration of Chinese students could be realized after their training period. The cost-benefit calculation of Chinese migration would look different if return migration of top graduates were to occur on a larger scale, as a result of the steadily raising skill premium in China and of the aggressive recruiting policies of Chinese universities. Given that our current understanding of return migration of the high-skilled is very limited, this is an important area for future research.

[12] However a survey of post-docs found only small differences between Chinese and Americans in terms of hours worked (50.5 hours per week versus 49.8; Brumfiel 2005)

[13] 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.

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Tables

Table 1: Using biographic information to verify the quality of the name matching

	With Chinese name
Right Match	88.2% are educated in China
Wrong Match	11.8% not educated in China (5.1% Taiwan)
	Educated in China
Right Match	95.6% have a Chinese name
Wrong Match	4.4% do not have a Chinese name

Table 2: Descriptive statistics on scientific output

	Chinese students (n=2,380)		NSF fellows (n=336)		All other students (n=13,357)	
	Mean	SD	Mean	SD	Mean	SD
First-authored pubs	1.14	1.50	1.45	1.55	0.87	1.22
Quality-adjusted first-authored pubs	5.77	8.82	10.42	10.16	4.49	7.15

Table 3: # of first-authored papers

	(1)	(2)	(3)
Chinese student	0.274***	0.298***	0.271***
	(0.029)	(0.035)	(0.029)
NSF doctoral fellow	0.457***	0.337***	0.330***
	(0.057)	(0.052)	(0.057)
University FE	No	Yes	No
Advisor FE	No	No	Yes
Observations	16,073	16,050	12,495
Number of clusters		159	2,187

Note: Specification (1) is a Poisson regression with robust standard errors, specification (2) and (3) are estimated by Poisson Quasi-Maximum Likelihood. All specifications include year of graduation and subfield fixed effects. The dependent variable is the number of first-authored publications which is based on the papers published between three years before graduation and the year of graduation.

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: # of quality-adjusted first-authored papers

	(1)	(2)	(3)
Chinese student	0.251***	0.309***	0.264***
	(0.033)	(0.041)	(0.033)
NSF doctoral fellow	0.625***	0.281***	0.330***
	(0.065)	(0.050)	(0.063)
University FE	No	Yes	No
Advisor FE	No	No	Yes
Observations	16,073	16,050	12,489
Number of clusters		159	2,185

Note: Specification (1) is a Poisson regression with robust standard errors, specification (2) and (3) are estimated by Poisson Quasi-Maximum Likelihood. All specifications include year of graduation and subfield fixed effects. The dependent variable is the number of first-authored publications weighted by journal impact factor. This is based on the papers published between three years before graduation and the year of graduation.

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Baccalaureate-origin institutions for PhD graduates in S/E from US Universities

Baccalaureate-origin Institution	Country	Rank	All S/E doctorates	Life sciences	Physical Sciences	Engineering
Tsinghua Univ	China	1	542	17	104	421
Beijing Univ	China	2	435	139	221	75
Seoul National Univ	Korea	3	239	56	76	107
Cornell Univ	USA	4	210	108	58	44
Univ of California-Berkeley	USA	5	207	92	59	56
National Taiwan Univ	Taiwan	6	176	64	49	63
Massachusetts Inst of Tech	USA	7	171	44	64	63
Univ of Sci & Tech China	China	8	157	20	87	50
Univ of Illinois at Urbana-Champaign	USA	9	153	70	27	56
Fudan Univ	China	10	140	49	65	26
Nanking Univ	China	11	138	42	68	28
Univ of Mumbai	India	12	136	55	23	58
Pennsylvania State Univ-Main Campus	USA	13	136	70	23	43
Univ of Michigan-Ann Arbor	USA	14	134	52	34	48
Shanghai Jiaotong Univ	China	15	133	8	27	98
Univ of Florida	USA	16	132	71	23	38
Nankai Univ	China	17	128	43	65	20
Univ of Wisconsin-Madison	USA	18	125	74	27	24
The Univ of Texas at Austin	USA	19	122	58	30	34
Univ of California-Davis	USA	20	119	75	29	15
Harvard Univ	USA	21	118	59	48	11
Brigham Young Univ	USA	22	116	52	39	25
Univ of California-Los Angeles	USA	23	116	61	38	17
Zhejiang Univ	China	24	115	9	31	75
China Univ of Sci and Tech	China	25	115	20	68	27
Yonsei Univ	China	26	112	21	28	63
Univ of Virginia-Main Campus	USA	27	106	50	29	27
Texas A&M Univ	USA	28	106	62	18	26
Rutgers Univ	USA	29	105	55	25	25
Univ of California-San Diego	USA	30	103	62	24	17
Virginia Polytechnic Inst and State Univ	USA	31	102	45	23	34
Wuhan Univ	China	32	101	36	34	31
North Carolina State Univ at Raleigh	USA	33	97	31	27	39
Middle East Technical Univ	Turkey	34	95	10	24	61
Stanford Univ	USA	35	94	45	27	22
Indian Inst of Tech (IIT) - Madras	India	36	93	0	14	79
Tianjin Univ	China	37	93	3	24	66
Univ of Minnesota-Twin Cities	USA	38	93	41	23	29
Ohio State Univ-Main Campus	USA	39	92	43	21	28
Indian Inst of Tech (IIT) - Kharagpur	India	40	89	5	29	55
Other institutions			14,352	5,997	4,427	3,928
Total			20,057	7,909	6,151	5,997

Source: Data from NORC(2008) based upon the NSF Survey of Earned Doctorates

Table 6: List of universities in the sample with statistics of interest

	university	tier	R & D exp.	total # students	# NSF fellows	Chinese (total)	Chinese (%)
1	California Institute of Technology	1	36.9	186	26	16	8.6%
2	Harvard University	1	30.3	245	71	23	9.4%
3	University of California-Berkeley	1	29.5	449	37	17	3.8%
4	University of Illinois-Urbana	1	29.2	413	7	40	9.7%
5	Texas A&M University	1	24.7	315	2	45	14.3%
6	Georgia Institute of Technology	1	24.4	183	1	24	13.1%
7	University of California-San Diego	1	23.6	206	3	11	5.3%
8	University of California-Los Angeles	1	23.3	285	3	28	9.8%
9	University of Texas-Austin	1	22.7	273	4	31	11.4%
10	Rutgers	1	22.0	131	0	50	38.2%
11	Massachusetts Institute of Technology	1	21.5	258	41	20	7.8%
12	Northwestern University	1	21.3	228	5	34	14.9%
13	University of North Carolina-Chapel Hill	1	21.0	311	6	18	5.8%
14	Purdue University	2	20.4	288	1	50	17.4%
15	Pennsylvania State University	2	19.6	229	3	24	10.5%
16	Cornell University	2	19.2	210	4	22	10.5%
17	University of Washington-Seattle	2	18.6	192	2	11	5.7%
18	University of Colorado	2	18.4	199	2	6	3.0%
19	University of California-Irvine	2	17.9	216	0	15	6.9%
20	University of Wisconsin-Madison	2	17.9	445	15	30	6.7%
21	Stanford University	2	17.8	232	31	28	12.1%
22	Johns Hopkins University	2	17.1	99	0	10	10.1%
23	University of Michigan	2	16.6	264	2	34	12.9%
24	Louisiana State University	2	16.5	95	0	9	9.5%
25	Emory University	2	16.4	123	0	36	29.3%
26	Michigan State University	2	15.1	191	1	49	25.7%
27	SUNY-Stony Brook	2	15.0	126	0	43	34.1%
28	University of Utah	2	14.9	179	2	15	8.4%
29	University of Chicago	2	14.8	191	8	36	18.8%
30	University of Arizona	2	14.7	140	2	23	16.4%
31	University of Pennsylvania	2	14.6	249	2	41	16.5%
32	Virginia Polytechnic Institute	2	14.3	64	0	8	12.5%
33	University of Florida	2	14.0	284	3	26	9.2%
34	Princeton University	2	13.9	122	6	32	26.2%
35	University of Akron	2	13.7	66	0	10	15.2%
36	SUNY-Buffalo	2	13.7	169	0	24	14.2%
37	University of South Carolina	2	13.6	130	1	16	12.3%
38	University of Southern Mississippi	2	12.3	27	0	4	14.8%
39	University of Pittsburgh	2	12.3	132	0	24	18.2%
40	University of Minnesota	2	12.2	228	3	35	15.4%
41	Arizona State University Main	2	11.8	92	0	2	2.2%
42	Ohio State University	2	11.6	227	0	43	18.9%
43	University of PR-Rio Piedras	2	11.5	29	0	1	3.4%
44	University of Southern California	2	11.0	126	0	18	14.3%
45	University of Maryland-College Park	2	10.7	118	1	12	10.2%

Table 5 - List of universities, continued

	university	tier	R & D exp.	total # students	# NSF fellows	Chinese (total)	Chinese (%)
46	University of Notre Dame	2	10.5	83	1	10	12.0%
47	University of Georgia	3	9.9	47	1	3	6.4%
48	Wayne State University	3	9.9	157	0	25	15.9%
49	University of California-Davis	3	9.4	122	0	18	14.8%
50	Florida State University	3	9.0	95	0	10	10.5%
51	Colorado State University	3	9.0	78	0	4	5.1%
52	Yale University	3	8.4	218	15	15	6.9%
53	New Mexico State University	3	8.3	28	0	3	10.7%
54	North Carolina State University	3	8.2	99	0	10	10.1%
55	Washington University	3	8.1	97	0	29	29.9%
56	Vanderbilt University	3	8.0	78	0	5	6.4%
57	University of California-Santa Cruz	3	7.9	95	2	8	8.4%
58	University of Iowa	3	7.9	146	0	26	17.8%
59	Duke University	3	7.8	159	5	27	17.0%
60	Columbia University	3	7.5	174	6	42	24.1%
61	University of Delaware	3	7.5	91	0	10	11.0%
62	Washington State University	3	7.1	57	0	4	7.0%
63	Clemson University	3	7.1	66	0	17	25.8%
64	University of Oklahoma	3	6.9	74	0	21	28.4%
65	University of Illinois-Chicago	3	6.8	131	0	20	15.3%
66	Boston College	3	6.8	113	1	15	13.3%
67	University of Arkansas	3	6.6	67	0	12	17.9%
68	University of Virginia	3	6.5	154	0	14	9.1%
69	University of Nebraska	3	6.4	100	0	18	18.0%
70	Brown University	3	6.4	66	0	20	30.3%
71	New York University	3	6.3	91	0	50	54.9%
72	Rice University	3	6.3	133	1	16	12.0%
73	University of Houston	3	6.2	115	0	30	26.1%
74	Iowa State University	3	6.2	191	0	43	22.5%
75	University of Kansas	3	6.1	127	0	10	7.9%
76	University of Kentucky	3	6.0	58	2	8	13.8%
77	University of Tennessee	3	5.7	86	1	7	8.1%
78	University of Cincinnati	3	5.6	108	0	5	4.6%
79	Rensselaer Polytechnic Institute	3	5.6	53	0	20	37.7%
80	University of Missouri-Columbia	3	5.5	70	0	8	11.4%
81	University of Connecticut	3	5.4	101	1	23	22.8%
82	University of Oregon	3	5.3	54	0	1	1.9%
83	Mississippi State University	3	5.3	24	0	5	20.8%
84	University of California-Riverside	3	5.3	96	0	22	22.9%
85	University of Massachusetts-Amherst	4	5.2	126	0	13	10.3%
86	Georgia State University	4	5.1	45	0	10	22.2%
87	North Dakota State University	4	5.0	31	0	5	16.1%
88	Texas Tech University	4	4.9	30	0	5	16.7%
89	Case Western Reserve University	4	4.7	107	0	36	33.6%
90	Carnegie Mellon University	4	4.7	47	1	3	6.4%

Table 5 - List of universities, continued

	university	tier	R & D exp.	total # students	# NSF fellows	Chinese (total)	Chinese (%)
91	University of California-Santa Barbara	4	4.6	133	2	9	6.8%
92	Boston University	4	4.3	77	0	36	46.8%
93	University of Rochester	4	4.3	92	0	20	21.7%
94	University of Maryland-Baltimore County	4	4.3	21	0	5	23.8%
95	Miami University (OH)	4	4.2	55	0	18	32.7%
96	University of Montana	4	4.1	29	0	2	6.9%
97	Virginia Commonwealth University	4	3.9	40	0	3	7.5%
98	Brandeis University	4	3.8	92	1	24	26.1%
99	University of Wyoming	4	3.7	41	0	4	9.8%
100	Tufts University	4	3.6	39	0	2	5.1%
101	Oregon State University	4	3.5	97	0	10	10.3%
102	Auburn University	4	3.3	60	0	28	46.7%
103	University of Texas-Arlington	4	3.2	36	0	10	27.8%
104	Clarkson University	4	3.2	15	0	2	13.3%
105	University of Nevada-Reno	4	3.2	53	0	3	5.7%
106	Bowling Green State University	4	3.1	50	0	7	14.0%
107	Howard University	4	3.1	37	0	3	8.1%
108	University of Louisville	4	3.1	45	0	4	8.9%
109	University of Alabama	4	3.1	69	0	17	24.6%
110	Temple University	4	3.1	62	0	14	22.6%
111	University of Wisconsin-Milwaukee	4	2.8	52	0	17	32.7%
112	Southern Illinois University-Carbondale	4	2.8	19	0	11	57.9%
113	University of South Florida	4	2.7	50	0	2	4.0%
114	University of New Mexico	4	2.7	58	0	31	53.4%
115	Dartmouth College	4	2.6	54	0	12	22.2%
116	Lehigh University	4	2.6	20	0	3	15.0%
117	West Virginia University	4	2.5	46	0	12	26.1%
118	Oklahoma State University	4	2.4	57	0	6	10.5%
119	University of Idaho	4	2.4	35	0	4	11.4%
120	Brigham Young University	4	2.4	57	0	20	35.1%
121	SUNY College of Env. Sci & Forestry	4	2.4	23	0	9	39.1%
122	University of North Texas	4	2.4	35	0	15	42.9%
123	Kent State University	4	2.3	29	0	4	13.8%
124	SUNY-Binghamton	4	2.3	44	1	7	15.9%
125	Kansas State University	4	2.3	55	0	12	21.8%
126	University of New Hampshire	4	2.2	36	0	10	27.8%
127	Syracuse University	4	2.1	54	0	10	18.5%
128	South Dakota State University	4	1.9	13	0	4	30.8%
129	Wichita State University	4	1.9	15	0	3	20.0%
130	Florida International University	4	1.9	13	0	5	38.5%
131	Western Michigan University	4	1.9	10	0	3	30.0%
132	SUNY-Albany	4	1.9	18	0	6	33.3%
133	San Diego State University	4	1.9	14	0	1	7.1%
134	George Washington University	4	1.8	27	0	2	7.4%
135	University of Texas-El Paso	4	1.8	10	0	0	0.0%

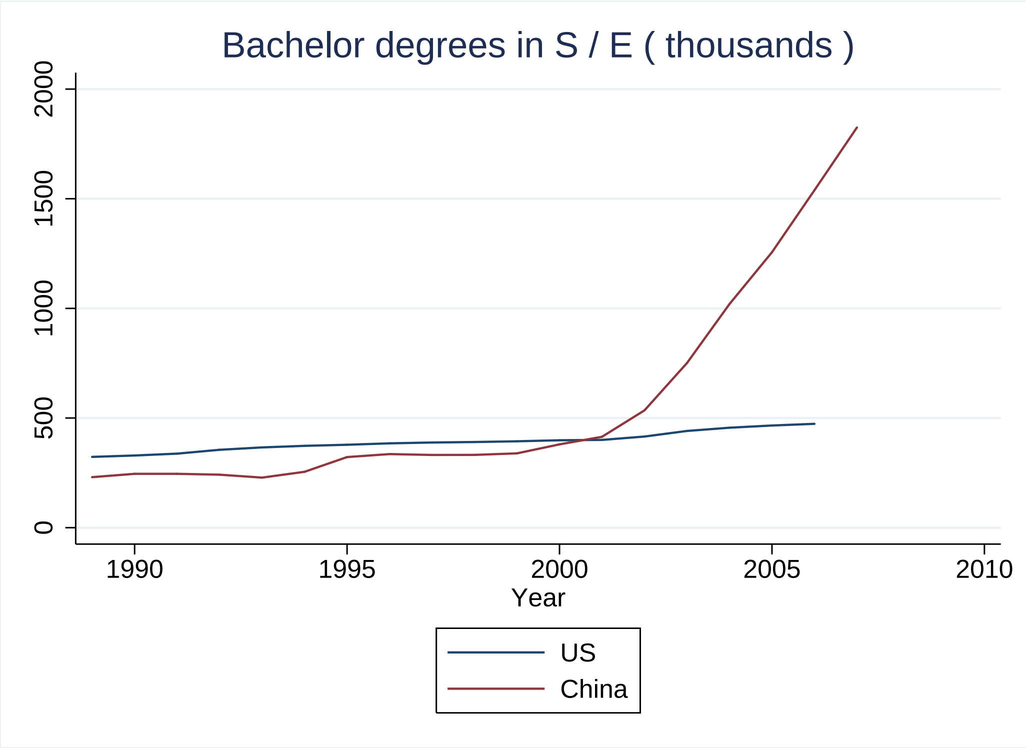
Table 5 - List of universities, continued

	university	tier	R & D exp.	total # students	# NSF fellows	Chinese (total)	Chinese (%)
136	University of Toledo	4	1.7	47	0	5	10.6%
137	University of Alabama-Birmingham	4	1.7	36	0	8	22.2%
138	Ohio University	4	1.7	56	0	12	21.4%
139	University of Missouri, St Louis	4	1.7	49	0	11	22.4%
140	University of Memphis	4	1.6	27	0	11	40.7%
141	Baylor University	4	1.6	32	0	1	3.1%
142	Georgetown University	4	1.6	60	0	11	18.3%
143	University of Missouri-Kansas City	4	1.6	24	0	14	58.3%
144	Utah State University	4	1.6	52	0	6	11.5%
145	Florida Atlantic University	4	1.5	20	0	3	15.0%
146	University of Denver	4	1.5	12	0	1	8.3%
147	Marquette University	4	1.4	32	0	12	37.5%
148	Tulane University	4	1.4	54	0	6	11.1%
149	Wake Forest University	4	1.3	45	0	5	11.1%
150	University of Maine	4	1.3	22	0	2	9.1%
151	University of North Dakota	4	1.2	26	0	1	3.8%
152	Illinois Institute of Technology	4	1.1	10	0	3	30.0%
153	Drexel University	4	1.0	23	0	3	13.0%
154	Northern Illinois University	4	0.9	32	0	1	3.1%
155	Michigan Technological University	4	0.9	18	0	6	33.3%
156	University of Miami (FL)	4	0.9	39	0	5	12.8%
157	University of Mississippi	4	0.7	16	0	3	18.8%
158	University of Rhode Island	4	0.7	25	0	9	36.0%
159	Florida Institute of Technology	4	0.5	12	0	1	8.3%
160	Clark University	4	0.4	23	0	8	34.8%
161	Loyola University of Chicago	4	0.4	41	0	7	17.1%

Notes: R & D expenditures refers to 2007 R&D expenditures in chemistry in million USD. The number of students, Chinese students and NSF fellows are based on students graduating from chemistry departments between 1999 and 2008

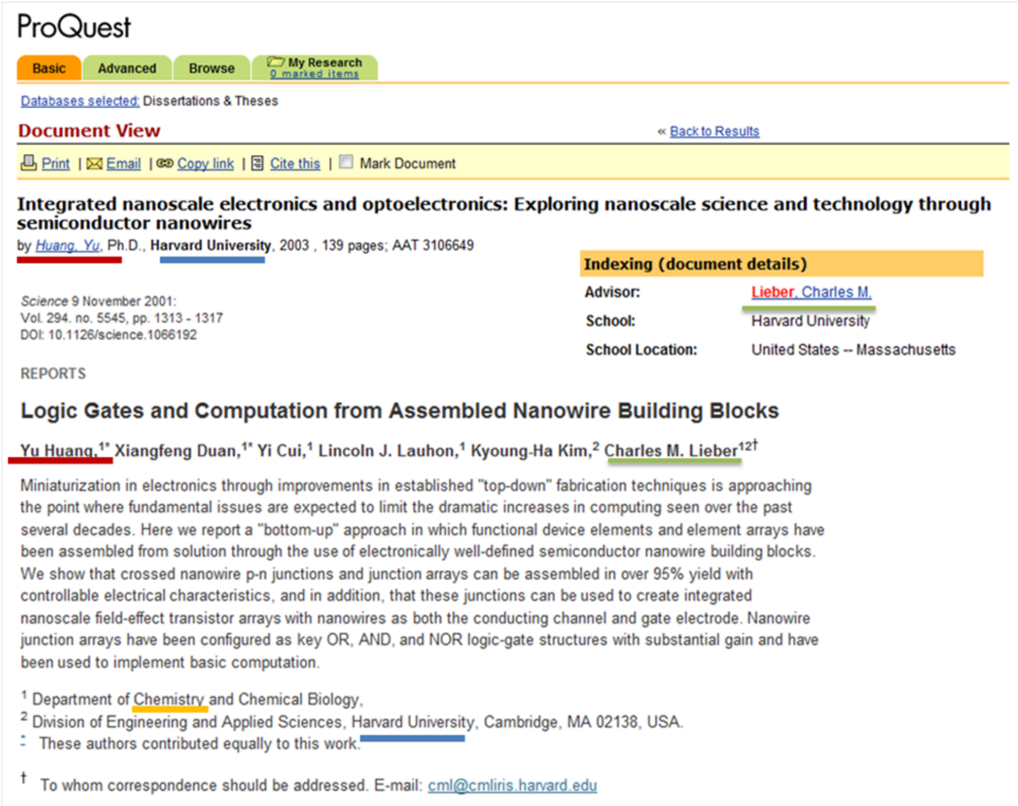
Figures

Figure 1: **Evolution of the number of bachelors in S/E graduating from Chinese universities**



Source: Chinese data computed from the Chinese statistical yearbook, various years. US Data from the National Science Foundation.

Figure 2: **Illustrating the matching process**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REPORTS

Logic Gates and Computation from Assembled Nanowire Building Blocks

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Miniaturization in electronics through improvements in established "top-down" fabrication techniques is approaching the point where fundamental issues are expected to limit the dramatic increases in computing seen over the past several decades. Here we report a "bottom-up" approach in which functional device elements and element arrays have been assembled from solution through the use of electronically well-defined semiconductor nanowire building blocks. We show that crossed nanowire p-n junctions and junction arrays can be assembled in over 95% yield with controllable electrical characteristics, and in addition, that these junctions can be used to create integrated nanoscale field-effect transistor arrays with nanowires as both the conducting channel and gate electrode. Nanowire junction arrays have been configured as key OR, AND, and NOR logic-gate structures with substantial gain and have been used to implement basic computation.

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Proquest Dissertation and Abstracts (upper part of the figure) has information on the name of the student, name of the advisor, university and year of graduation. The publication (lower part of the figure) has information on the affiliation of each author. A publication is matched to a student if nine criteria are successfully met: The first author of the publication needs to have the (1) last name of the student (2) first initial of the student (3) correct departmental affiliation of the student (4) correct university affiliation of the student; and one of the coauthor on the paper had to have (5) the last name of the advisor (6) the first initial of the advisor (7) the correct departmental affiliation of the advisor and (8) the correct university affiliation of the advisor. Finally, the paper had to be published (9) no earlier than 3 years prior to the graduation of the student and no later than the year of graduation.

Figure 3: **Fraction of Chinese students by university**

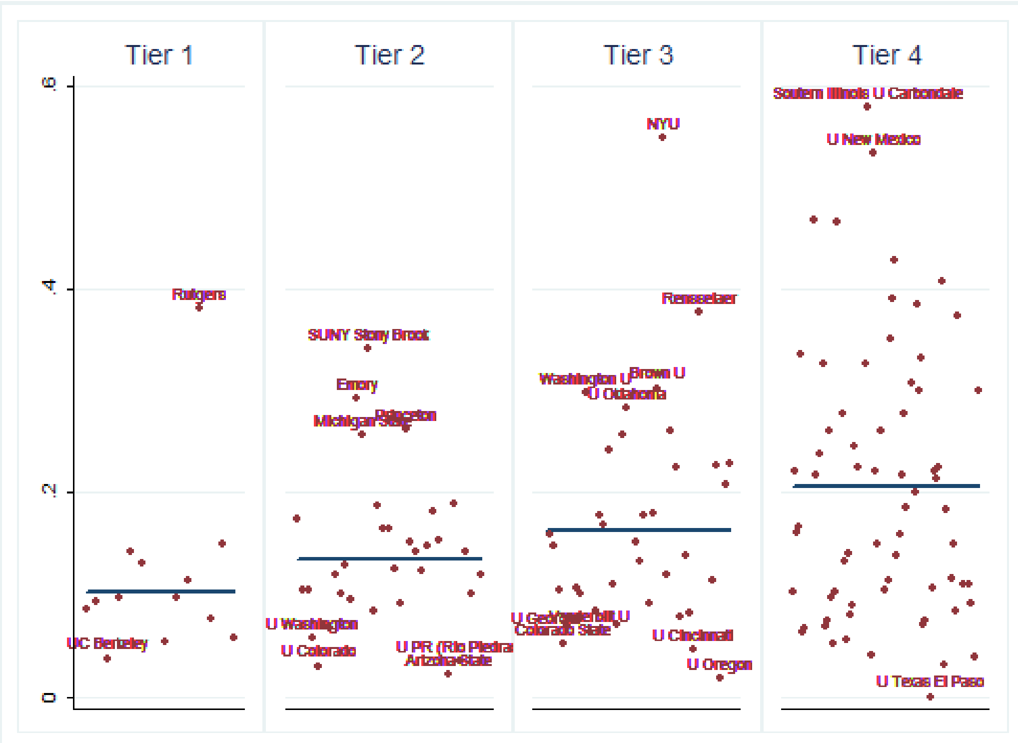

Figure 4: **Box-plot of the distribution of first-authored publications**

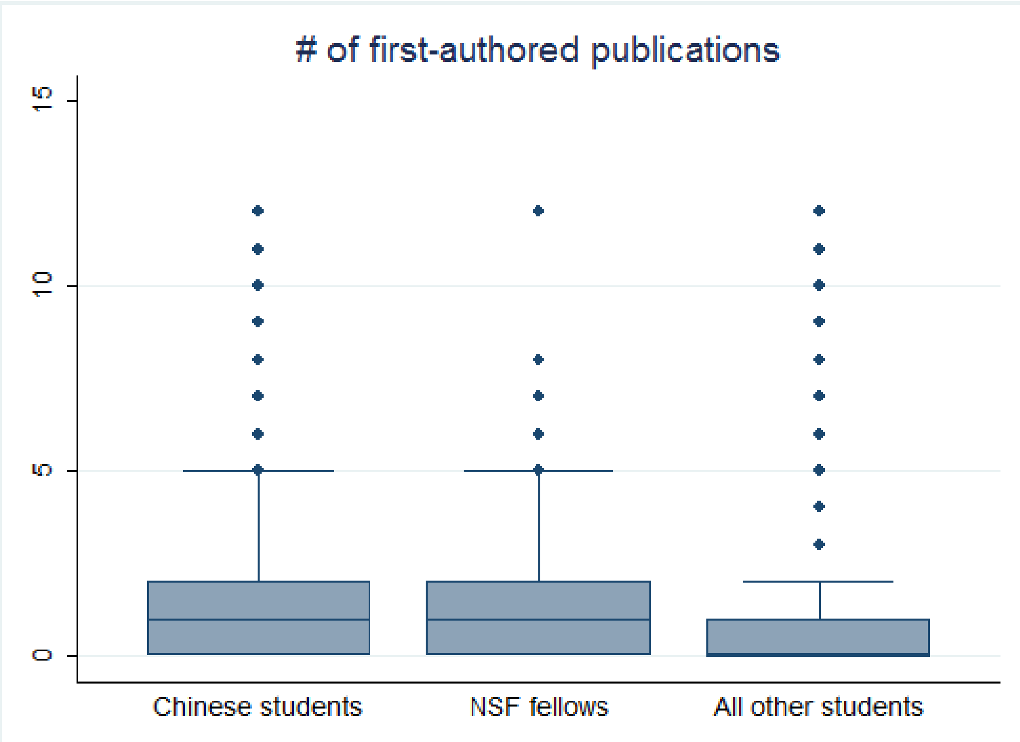

Figure 5: **Box-plot of the distribution of first-authored publications adjusted for quality**