Article Title Page

Skilled flows and selectivity of Chinese scientists at global leading universities between 1998 and 2006

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Structured Abstract
Purpose
The purpose of this paper is to closely examine the flows and selectivity of a scientific brain drain from China against the background of global talent competition.
Design/methodology/approach
This paper is derived from an empirical study, which randomly surveyed 451 Chinese scientists at leading global universities. Based on their biographical information, descriptive analysis and logistic regression not only demonstrates migration patterns of Chinese scientists, but also reveals their demographic profiles between 1998 and 2006.
Findings
The findings of this study show that the scientific community in China experienced increasing personnel exchange with the English academia during the observation period. Emigrant scientists from China were selected positively in terms of educational background, and the pattern seemed to turn stronger over time. By contrast, returnee scientists were selected negatively from those who studied abroad. The predominant mode of migration was both an ongoing brain drain and an emerging brain circulation, and the latter was largely pushed by domestic degree holders with overseas experience.
Originality/value
This empirical study enriches our understanding of international migration in the scientific community, and helps explain China's strategy in achieving rapid scientific development. Although national strategies targeting the research diaspora make a limited contribution in luring prominent scholars back home, a brain circulation can be realized by sending domestic scientists abroad for short-period training or visiting.

Keywords: Brain drain, Brain circulation, Chinese scientists, Science policy, Universities, Sciences, China

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Running Heads:
Skilled flows and selectivity

Skilled Flows and Selectivity of Chinese Scientists at Global Leading Universities between 1998 and 2006

I. Introduction

As a global "knowledge economy" has been gradually emerging in the world since the late 20th century (OECD 1996), many countries have actively expanded their national talent pools. Besides education reform and R&D investment, governments in the developed world often meet the increasing demand for skilled workers by employing highly educated migrants from foreign countries on a temporary or permanent basis (Abella 2006). Due to enormous imbalances in the directions of skilled flows (Gill 2005), however, the large welfare brought by skilled migration is unevenly distributed between nations, and the problem of "brain drain" has persisted in the sending countries, most of which belong to the developing world (Bhagwati 1979; Dickson 2003).

In recent years, students of migration have gradually realized that skilled emigrants can also bring benefits to their home countries, such as remittances, returnees, technology transfer, and foreign investment. For example, some developing countries, particularly China and India, are actively recruiting their skilled expatriates back home with favorable conditions (Xiang 2003; Kapur and McHale 2005, 163-176). A brain drain can actually turn into a gain for developing countries, if its positive effects outweigh the negative ones. In this sense, skilled emigration should be viewed not as loss of talent, but an important means of development.

The overall benefits from skilled migration to source countries, or those left behind, are not entirely clear (Bhatnagar 2004). Nor do source countries fully understand how to take advantage of their national human resources in foreign countries (Ackers 2005a). The research agenda of migration studies has realized the gap between available knowledge and policy needs in this regard. As a response, this paper is devoted to a better understanding of the consequences of brain drain in general and the migration of scientists in particular. Its primary research goal is directed to analyzing the following questions from a sending country perspective: how are Chinese scientists distributed in the world, how do they flow across countries, and how are they selected when they go abroad and return?

We chose Chinese scientists as the object of study for several reasons. Migration of Chinese scientists is very dynamic in terms of length, frequency, destination, and program (Séguin et al. 2006; Zweig, Fung, and Han 2008). China's scientific growth is also remarkable in recent years, which deserves intensive investigation of the changing composition of its research workforce (Adams, King, and Ma 2009). From a policy perspective, it is pertinent to ask how the migration of its scientists has fostered China's scientific development.

This study focuses on the mobility status of Chinese scientists in three observation years, 1998, 2002 and 2006, because return migration in China had become phenomenal only from the late 1990s (Arunachalam and Doss 2000). The sample covers 451 individual scientists at global leading universities, who were selected from about 6,000 Chinese researchers in mainland China and seven English-speaking countries. The temporal and spatial scale of this study can help us map the geographic distribution of Chinese scientists and depict their migration patterns.

The content of this paper is organized as follows. Section 2 raises the research questions and related hypotheses after reviewing the underlying literature. Section 3 describes the data collection procedure and the variables. Section 4 analyzes the geographic distribution and migration flows of Chinese scientists, and Section 5 shows the selectivity of these flows. Section 6 presents the conclusions with a discussion of their policy implications.

II Literature review and research questions

Conventional wisdom tends to strongly associate "brain drain" with negative impacts (Patinkin

1968; Grubel and Scott 1966; Johnson 1979). Skilled emigration is believed to drain developing countries of their already small talent pool and thus deprive them of the human resource capable of developing their economies, which contributes to increasing economic and technological gaps in the world (Solimano 2001). Several theoretical models following the new growth literature also emphasize the negative effects of brain drain (Miyagiwa 1991; Haque and Kim 1995; Wong and Yip 1999).

However, dynamic patterns of international migration have renewed the debate on brain drain from the 1990s. The conception about skilled migration has shifted from human capital loss to benefits brought by brain circulation, which can be realized largely through return migration (Gaillard and Gaillard 1998). The original loss of brain drain can be partially or even more than offset by attracting former skilled expatriates back home. Several studies also theorize that return migration transfers knowledge from receiving countries and contributes to the endogenous growth of source countries (Domingues Dos Santos and Postel-Vinay 2003; Saxenian 2005; Dustmann, Fadlon, and Weiss 2011).

In the national academia of a country, the emigration of its native scientists may indicate a loss of research capability and scientific knowledge. The famous historical cases include the exodus of Jewish scientists to America in the 1930s or the outflow of Russian scientists to the West after the Cold War. Nonetheless, brain circulation, if it occurs sequentially, provides an important mechanism of knowledge transfer and international collaboration (Meyer, Kaplan and Charum 2001; Ackers 2005b). Migrants returning with cutting-edge knowledge and international networks are considered important transmitters of technology and knowledge (Davenport 2004). Since it is often impossible or too costly to codify all knowledge and transfer tacit knowledge, returnee scientists can play a crucial and effective role in knowledge diffusion by personal interaction or joint research projects with domestic researchers.

Although inflows of returnees often can not match outflows of emigrant scientists, temporary migration of domestic scholars also fosters knowledge flows as they gain experience abroad after short-term stays. Frequent visits help the local scientific community join global networks and collaborate with foreign scientists (Regets 2007; Defazio, Lockett, and Wright 2009). Skilled emigration can be beneficial to a source country if its overseas scientists facilitate short-time visits of their domestic peers by developing an ethnic scientific network (Thorn and Holm-Nielsen 2006).

Few studies have systematically examined scientific emigration from a source country, partly because a comprehensive inquiry requires cross-sectional data covering both domestic and overseas scientists, and common demographic information is insufficient to retrieve individual migration history. As an exploratory attempt, this study tries to conduct a global survey and examine the migration patterns of the scientific brain drain from China. The survey was designed to answer the following two research questions and test two related hypotheses.

Q1: How were Chinese scientists distributed in the English academia, and how did they migrate internationally during the observation period?

Q2: Compared with the base population of scientists, how were emigrants and returnees selected in terms of key demographic indicators?

The second question is crucial to identifying the nature of the two migration flows. Here the base population of emigrants is all scientists who received undergraduate education in China; that of returnees refers to all those who obtained their highest degrees abroad, or who studied/worked abroad for at least two years, depending on the definition of returnees. The key demographic indicators include age, gender, discipline, and more importantly, educational background.

Students of migration have reached a consensus that skilled emigration generally has strong and positive selectivity (Kapur 2010, 69-102). Immigration policies in host countries, particularly those based on employment, generally screen migrants with high skills (Abella 2006). Workers with higher performance in the home country, driven by overseas opportunities, are also inclined to realize outmigration. Chiswick (1999) argues that positive self-selection can be generally expected in the migration process, though a higher income inequality in the place of origin might attenuate the selection effect. Such self-selection patterns are also observed in the world of science (Zuckerman 1988).

Here we expect not only that emigrant scientists are positively selected, but that their selectivity becomes stronger over time. The intensified selectivity may result from two trends – increasing information transparency and diverging migration opportunities. At the beginning of emigration, employers in the host country can not differentiate the skill levels of migrants effectively due to information asymmetry, so the selectivity is weak. After some years, the host country can screen qualified workers by a sorting process like the point system, and foreign employers can estimate the skill level of a foreign applicant more accurately after they become familiar with the labor qualification indicators of potential migrants.

With regard to scientific migration, foreign universities usually play the role of gate keepers and they have gradually accumulated experiences in admitting international students. Hence graduates from prestigious colleges in the source country are more likely to attend foreign doctoral programs than those from less prestigious ones. For the former group, past successful cases would stimulate the motivations of later cohorts and raise their expectations to seek overseas study opportunities. Moreover, overseas alumni networks of prestigious colleges can provide additional assistance to the admission of younger schoolmates and diminish the risks of application. Here, then, is our first hypothesis:

H1: Recent cohorts of Chinese emigrant scientists were more positively selected than old cohorts in terms of education background. In other words, the probability of overseas study or employment is increasing with the quality of education, and the association becomes stronger over time.

By contrast, negative selection often characterizes return migration (Borjas and Bratsberg 1996). Borjas (1989) finds a negative selection process by which the least successful foreign scientists were more likely to return from the USA. Stark Helmenstein, and Prskawetz (1997) also argue that low-ability workers are more likely to return from the foreign labor market, once employers know their real productivity and dismiss them. However, based on the data of migration between Eastern and Western Europe, Mayr and Peri (2009) demonstrate that the skills acquired in foreign countries contribute to a “return premium” in the home country, which leads to positive selection in return migration. There is also some empirical evidence supporting this trend (Dustmann and Weiss 2007; Gundel and Peters 2008)

Considering China is still lagging behind the developed countries in the arena of science, we hypothesize that returnee scientists are more likely to be negatively selected. However, the negative selectivity is expected to be weakened over time, as more emigrants are attracted by the rapidly growing economy and lured back by China’s talent programs targeting outstanding returnees. The second hypothesis expects that:

H2: Returnee scientists who have come back in recent years were less negatively selected from overseas Chinese than those who returned in earlier periods in terms of educational background and research productivity.

III Data collection and variables

This present study mainly relied on a survey to collect the biographical data. We then used the CVs available on the internet as a supplementary source to fill missing values and check reliability.

The target populations of this study are Chinese scientists in four selected fields at global leading universities. The four fields are mathematics, physics, chemistry, and biology[1]. Many more scientists belong to these fields relative to other small disciplines, and migration trends of Chinese scientists in these fields arguably represent general migration patterns of academics between China and major destination countries.

In order to obtain a better coverage of the target population, we selected all the universities in mainland China and seven English-speaking countries from the 501 universities on the 2009 Academic Ranking of World Universities (ARWU) by Shanghai Jiaotong University (IHE 2009)[2]. The seven countries include major immigration countries, including the USA, United Kingdom, Canada, Australia, and New Zealand, as well as two city states, Singapore and Hong Kong[3]. There are 18 universities in mainland China and 243 universities in the seven countries on the 2009 Jiaotong list.

The procedure of identification in this study results from three search steps at the university, departmental, and individual level. As a cost-effective strategy in the first step, we selected 120 universities systematically from the 234 institutions in five English countries on the ranking list. All of the seven universities in Hong Kong and Singapore were selected, as well as the 18 in mainland China. We then visited the websites of 522 departments[4] at the 145 selected universities by searching related key words[5] and reading the web pages of their faculty members[6] carefully to identify each Chinese name (Table 1).

The identification procedure bifurcated at the individual level. We identified every Chinese scientist in the five English countries, since a stratified sampling was already conducted at the university level according to their rankings. With regard to mainland China, Hong Kong and Singapore, where the local academia largely consists of Chinese, we compiled a name list of mainlanders firstly based on the information on the department websites. There are 5,556 scientists in China and 298 in the two city states on the list, and we selected half of them systematically for identification. We identified 3,588 scientists in total finally, and recorded the name, email address, CV availability, and official/personal web pages of each scientist. This roster was used as a sampling frame for the following survey.

Table 1 Frequency of identified universities, departments, and population

Region	*University*	*Department*	*Target population*	*Identified Scientists*
English countries	120	426	1328[1]	664
Hong Kong and Singapore	7	26	298	146
China	18	70	5556	2778
Total	145	522	7182	3588

[1] Nowadays “life sciences” more frequently refer to a variety of branches in biological studies from genetics to ecology. This paper uses the phrase interchangeably with the term “biology”.
[2] See Liu and Cheng (2005) for a detailed introduction of the ranking list.
[3] The sovereignty of Hong Kong has been transferred from the United Kingdom to China in 1997. However, Hong Kong can be viewed as a “foreign country” outside mainland China, if we take its high autonomy and westernized academia into consideration.
[4] Some research units use “school” in their names and they are treated as departments.
[5] For example, we can find the website address of the Mathematics Department at Harvard University by searching “Harvard” and “math” together with Google.
[6] Most of the departments provide the profile of their faculty members under the column “people” or “research” of their websites.

Note: This figure is estimated by doubling the 664 identified scientists in the five English countries.

Over 2,400 of the identified scientists (1,639 domestic scientists and 796 overseas scientists) were invited to join an online survey, because the email addresses of the remaining people are not available on their web pages. Nearly 500 respondents returned questionnaires after the two waves of the survey. If we assume 10% of the email addresses are false, invalid, or seldom checked by their owners, the overall response rate reaches over 20%. After a process of data cleaning, we obtained 451 effective observations in total.

We then used the sampling frame to weight the sample, thereby improving its representativeness. The sampling frame offers three key variables – location, field, and university ranking. Because of the email availability, less than two thirds of the domestic scientists received the invitation letters, while almost all overseas scientists did, indicating the latter were over sampled. Hence we divided the sample into two parts by location (the domestic part and the overseas part), and weighted each part separately. The two parts were categorized into 12 and eight cells by field and university ranking, respectively. So were the two corresponding parts of the sampling frame. The frequency weights were generated as the ratio of a cell's frequency of the sample to that of the sampling frame. We then assigned the weights to the observations according to their cells after modifying several extra large weights[7].

IV Geographic distribution and migration flows

The survey provides a clear picture of the career paths of Chinese scientists at different stages through retrospective questions, such as birthplace, hukou status before college education, working affiliation, university education, as well as duration overseas.

We first categorized the 31 provinces in mainland China into three regions according to their development status (see Appendix II), and compared the composition of regional population in 1990 with that of scientists in our sample[8]. Proportionally, the developed provinces are more likely to be the birthplaces of the scientists (Table 2). Although population aged over six in the developed region only represented 29.2% of the national population, scientists born in the region constituted over a third of all those at leading universities, and the regional share among those with overseas study is even higher (41.1%). By contrast, those from the least developed region would have less chance to study abroad (7.9% vs 2.6%).

However, the regional composition of scientists is consistent, if not identical, with that of population with tertiary education, which indicates that regional human capital level determines the number of scientific talent of local origin. It might also explain the rural/urban differences in China's talent geography. Nearly 80% of the Chinese population had rural hukou in 1990, but only 45% of the leading scientists in our sample were of rural origin, and 43.5% of those with a foreign degree were so. It seems access to Chinese college education, instead of overseas study opportunities, largely hindered the research career prospect of a rural student.

Table 2 Proportion of population in 1990 and scientists in the sample by region (%)

[7] It should be noted that this weighting scheme has adjusted the disciplinary and ranking distributions of the sample, but it does not address the non-response bias in terms of other variables. Comparison of demographic attributes between the two waves of survey shows that selection bias is probably not too serious to change our major findings.

[8] We took regional population in 1990 as the reference base because it is the earliest year when the youngest individual in our sample was already over six.

Region	Population aged over six	Highly educated population	Scientists at leading universities	Scientists with overseas study
Developed region	29.2	37.8	35.5	41.1
Less developed region	62.9	54.7	56.9	56.2
Least developed region	7.9	7.4	7.6	2.6
Total	100	100	100	100

Source: Table 3-6, NBSC (1991)

We then used several temporal and spatial variables to identify the migration status of each individual in every observation year. This variable has three broad categories: stayers, emigrants, and returnees. Stayers are defined as those who obtained their highest degree in China and stayed overseas for no more than two years by a given year, while emigrants are defined as those who worked for a foreign institution in the given year. Returnees are composed of two groups: foreign degree holders at Chinese universities and domestic degree holders with at least two years of overseas experience.

The locations of Chinese scientists are categorized into three regions: mainland China, the USA, and the Rest of the World (ROW)[9]. The geographic distribution of Chinese scientists in the three regions had changed considerably between 1998 and 2006. Table 3 presents their regional proportions, the number of observations, and the extrapolated number of population according to their weights. Overall, Chinese scientists at the leading global universities grew from less than 3,500 to more than 6,100. The number of researchers at the 18 leading Chinese leading universities increased steadily from less than 2,500 to over 4,000[10], which implies an expansion by 63% in eight years. The talent pool of overseas Chinese expanded even more rapidly in the USA (129%) and the ROW (98%).

Table 3 Geographic distribution of Chinese scientists, 1998 - 2006

Year	China (%)	ROW (%)	US (%)	Total (%)	Observation	Population
1998	71.6	13.3	15.1	100	253	3444
2002	64.9	14.2	21	100	351	4754
2006	65.7	14.9	19.5	100	451	6136

Note: The figures of population are extrapolated according to the frequency weight. The average of the frequency weight is 13.6, which means that eight more observations can raise an extrapolated figure by one hundred.

Table 4 Distribution of migration groups, 1998-2006 (%)

Year	Stayer	Returnee	Emigrant	Total	Emigration rate	Return rate

[9] The ROW mainly covers six English-speaking countries (UK, Canada, Australia, New Zealand, Singapore, and Hong Kong), as well as other countries like Japan or Germany.

[10] It should be noted that not all researchers were formally employed in the figures. Doctoral students in their penultimate year before graduation are also included in the sample.

1998	54.2	17.4	28.4	100	28.4	38
2002	43.4	21.5	35.2	100	35.2	38
2006	33.3	32.4	34.3	100	34.3	48.6

Note:
1. Emigration rate is defined as the ratio between emigrants and all Chinese scientists in an observation year.
2. Return rate is defined as the ratio between returnees and all Chinese scientists with overseas experiences, including both emigrants and returnees.

Among the three groups with different migration status, returnees represented almost one third of all Chinese scientists in 2006, while their share was just 17.4% in 1998 (Table 4). Although the overall return rate remained unchanged between 1998 and 2002, it jumps to 48.6% in 2006, which indicates that half of those scientists with international experience for at least two years had returned to China by 2006. Meanwhile, the overall emigration rate only increased by six or seven per cent. It seems a balanced brain circulation, instead of a lop-sided brain drain, had started to occur in this period. However, it is necessary to analyze the composition of returnees to confirm this trend.

The nature of brain drain depends on emigrants' study and work locations. Since returnees include both foreign degree holders and visiting scholars, it is necessary to distinguish the former from the latter. Hence we further categorize all Chinese scientists into five types. Emigration of a Chinese scientist can take two forms - directly moving abroad as an independent researcher or indirectly immigrating abroad after acquiring a foreign doctoral degree. We designate the former as "emigration of scholars" and the latter as "emigration of students". The definitions of "returnee scholar" and "returnee students" are derived accordingly. Thus, "returnee students" refers to foreign degree holders who returned to China, and "returnee scholars" refers to domestically trained researchers who returned after staying overseas for two years or more.

The dichotomy is very helpful in revealing the composition of the scientific migrations between China and the host countries. The absolute majority of returnees were composed of returnee scholars between 1998 and 2006 (Table 5), and returnee students represented around 20% of all returnees. By contrast, most emigrant scientists obtained foreign doctorates before they were formally employed abroad. Emigrant students took the lion's share of China's research diaspora, and their proportion kept close to 80% in the period.

Table 5 Distribution of five migration types, 1998-2006 (%)

Year	*Stayer*	*Returnee student*	*Returnee scholar*	*Emigrant student*	*Emigrant scholar*	*Total*	*Emigration rate of scholars*	*Return rate of students*
1998	54.2	3.4	14.0	22.6	5.8	100	7.9	13.2
2002	43.4	3.7	17.8	26.0	9.1	100	13.0	12.3
2006	33.3	7.4	25.0	26.5	7.8	100	11.9	21.9

Note:
1. Emigration rate of scholars refers to the ratio between emigrant scholars and domestic degree holders.
2. Return rate of students refers to the ratio between returnee students and foreign degree holders.

If we exclude returnee scholars from the statistics, the return rate of returnee students is as low as 13.2% in 1998 (see the last column, Table 5). It jumped to 21.9% in 2006, but remained at a low level. However, we might exaggerate the gravity of the scientific brain drain here, since China did not train the emigrant students at the doctoral level. Most emigrant scientists had not accumulated enough expertise to conduct research independently when they pursed overseas study as college graduates. With the exception of those sponsored by the Chinese Government, they financed their tuition fees and living expenditure from private sources, particularly scholarships provided by foreign universities.

V. Selectivity of migration flows

According to a recent evaluation report of Chinese universities (Wu 2009), we classified the Chinese colleges mentioned by the respondents into four tiers. A list in the report covers all the 34 top colleges in mainland China (or "A-class" colleges, to put it in the author's words) and ranks them by selected indicators in natural sciences[11]. The classification adopted here is primarily consistent with the ranking list, and it made some adjustments according to qualification of students in the colleges.

As a gross indicator of the quality of graduates, college rankings substantially distinguish emigrant scientists from those left behind. We use "domestic degree holders" to designate those who were awarded their highest degree in China[12], and adopt "foreign degree holders" to refer to those who received their doctoral education abroad. We find that the latter were much more likely to graduate from prestigious colleges in China than the former. Nearly half (49.1%) of foreign degree holders obtained their bachelor degrees from colleges in the first or second tier, while only over a quarter (27.2%) of their domestic peers did so (Figure 1).

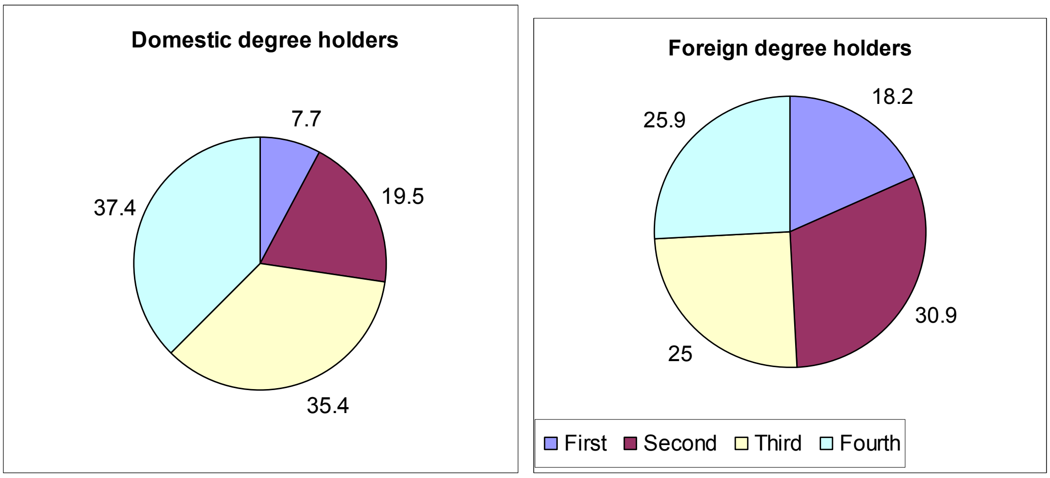

Figure 1 Composition of domestic/foreign degree holders by tier of college

We further checked the selectivity of foreign doctoral programs over cohort. The operational definition of cohort is the graduation year of the bachelor degree in this study. We categorized it into four dummy variables for the purpose of analysis. Scientists who received their bachelor degrees between 1977 and 1983 are defined as the early-reform cohort, and those who did so between 1984

[11] The Chinese version of the list is available online: http://edu.sina.com.cn/gaokao/2008-12-24/1805180859.shtml

[12] Here "the highest degree" is more accurate than "doctoral degree", because some domestic scientists only obtained master degrees.

and 1989 are defined as the pre-incident cohort. Here the "incident" refers to the Tiananmen Square protests in 1989. So those between 1990 and 1996 are defined as the post-incident cohort and those between 1997 and 2003 as the millennium cohort. The later cohorts generally consist of more scientists than the previous cohorts, which is the result of the expansive trend toward college enrollment and research personnel in China.

Despite the increasing stock of foreign degree holders, the number of scientists trained abroad in each cohort did not grow substantially. According to our estimates, nearly 400 of the early-reform cohort received a foreign education, and over 600 of the pre-incident cohort obtained foreign degrees, but a little more than 500 of each of the two younger cohorts did so. This stable trend implies that the competition for foreign education might have become more intense in recent years, as applicants of foreign doctoral programs probably increased substantially.

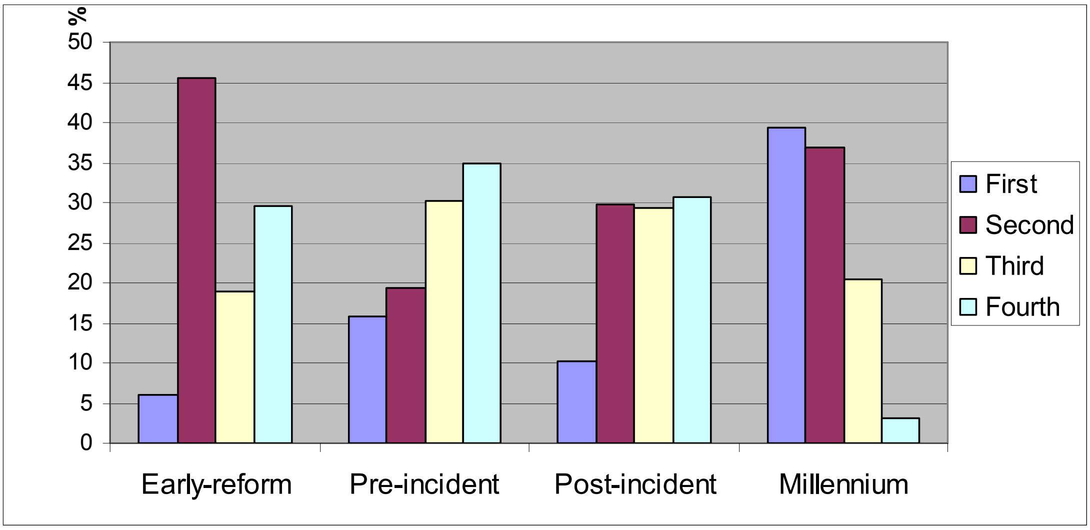

Figure 2 College background of foreign degree holders by cohort

Hence the selectivity of foreign doctoral programs appeared to turn stronger over time (Figure 2). The early-reform cohort was perhaps very different from the later cohorts in terms of selectivity, because the measurement used here might be less accurate in evaluating the quality of undergraduate education in the initial years after the restoration of the national entrance examination. The share of graduates from prestigious universities among foreign degree holders has demonstrated a clear increasing trend since the mid-1980s. Over one third (35%) of foreign degree holders in the pre-incident cohort graduated from colleges in the first or second tier, while 40% in the post-incident cohort did so. The positive selectivity became most intense for the millennium cohort, as three quarters of its foreign educated members are alumni of the upper two tiers of colleges. In addition, the stronger selectivity might partially result from the enrollment growth at prestigious colleges in China, as they admitted many students who would have otherwise attended less prestigious institutions.

Since multiple factors influence a Chinese scientist's chance of emigration, we used logistic regressions to disentangle their specific effects on foreign education[13]. As most of the independent variables in the logistic regressions are dummy variables, here we present the regression results in the format of odds ratios for easy interpretation. The odds-ratio is the exponential transformation (antilog) of the associated coefficients. For a dummy variable representing a category X, the odds-ratio

[13] Although probit models are generally considered to generate more precise estimation, logit models perform just as well and have the advantage of computational simplicity (Kropko 2007).

associated with X stands for the ratio of the odds of this category to that of the reference group, other things being equal.

The logit model focuses on the determinants of foreign doctoral education (Table 6). The dependent variable is dichotomous – whether a Chinese scientist obtained his highest degree from a foreign university or not. Its explanatory variables are specified in Table 5, as well as their odds ratios and statistical significances. To control for the effects of personal characteristics, we included variables for gender (male=0, female=1), tier of college (the third tier as the reference group), and field (chemistry as the reference group). Since age and cohort are highly correlated (r < -0.9), only cohort is included as the specification with it has a higher pseudo R-square.

The results show that the odds ratio between females and males differs by a factor of over 0.5, indicating women scientists are considerably less likely to receive foreign education than men of science. Compared with the pre-incident cohort, the later two cohorts are less likely to obtain a foreign doctoral degree. At the first glance, this finding seems counterintuitive as the number of Chinese overseas students has grown rapidly from the beginning of the 1990s. However, more applicants also mean more intense competition, and proportionally fewer students can be admitted by Western top universities. In addition, the odds for biologists are 1.2 higher than that for chemists, with the relatively high odds of physicists and mathematicians in between. With regard to the effects of college education, graduation from the first tier tripled the odds of foreign doctoral education and graduation from the second tier doubled them when compared with graduation from the third tier. The fourth tier had no significant effect relative to the third. These results show clearly that the best of the best were prone to study abroad.

Table 6 Explaining foreign education propensity of Chinese scientists

Explanatory Variable	*Odds Ratio*	
Female (vs. Male)	0.506072	**
Cohort (Reference group = Pre-incident)		
Early-reform	0.723037	
Post-incident	0.445025	***
Millennium	0.43936	***
Tier of college (Reference group = the third Class)		
First	3.652348	***
Second	2.682109	***
Fourth	1.184703	
Field (Reference group= Chemistry)		
Mathematics	1.837182	**
Physics	1.680064	*
Biology	2.228898	***
Observation		421
Pseudo R^2		0.0827

Note: *p<0.1, **p<0.05, ***p<0.01

In order to examine educational selectivity at doctoral level, this study adopts the 2009 Jiaotong ranking list as a reference for differentiating the quality of the doctoral universities of Chinese scientists (IHE 2009). A coding scheme aggregates all the universities into four categories from Class I to Class IV in accordance with their rankings on the Jiaotong list. For the purpose of simplicity, the top 50 institutions are grouped as "Class I", universities with rankings between 51 and 200 as "Class II", those between 201 and 400 as "Class III", and those below 400 as "Class IV". Those out of the list are integrated into the fourth category.

Next we attempted to test the effects of the selected predictors on the odds of foreign employment in 2006 upon completion of one's highest degree, so the following logit model only covers those who graduated by 2006 in both China and foreign countries. It has the specification similar to the previous model, but tier of college is replaced with class of the university where the doctorates were obtained (Table 7)[14]. Although the odds ratio between females and males (0. 662) is close to that in Table 5, there was no statistically significant difference by gender, indicating that the gender gap in the scientific emigration might be mediated by their access to foreign education. Contrary to the age effect on foreign education, we detect no clear cohort effect. Although older Chinese scientists were more likely to obtain foreign degrees than younger ones, it seems they were less likely to stay abroad.

The odds of foreign stay differed greatly by class of university. Graduates from universities in Class I and II were much more likely to work in foreign countries than those from Class III, as the former's odds ratios were around three times higher than the latter's. By contrast, the odds of staying abroad for graduates from Class IV were only over a third (42.6%) of that for those from Class III[15]. The results are statistically significant even after we controlled location of doctoral university. Compared with a domestic degree, a foreign degree boosted the odds of overseas employment by a factor of 8.73. Additionally, we find no significant disciplinary disparities between the four broad fields, except that the odds of foreign employment for biologists were almost twice as high as that for chemists.

Table 7 Explaining foreign employment of Chinese Scientists in 2006

Explanatory Variable	*Odds Ratio*	
Female (vs. Male)	0.6615273	
Cohort (Reference group = Pre-incident)		
Early-reform	0.5786015	
Post-incident	1.188181	
Millennium	1.565351	
Class of university (Reference group = Class III)		
Class I	4.985996	***
Class II	3.37645	**
Class IV	0.426458	**
Foreign degree (vs. Chinese degree)	8.738787	***
Field (Reference group= Chemistry)		
Mathematics	1.131893	
Physics	1.238349	
Biology	1.801179	
Observation		400

14 Duration is a stronger predictor of overseas stay, as one additional year outside China raises the odds of foreign stay by 17.6% if it is included in the model. However, we have to omit this variable because it is highly correlated with university rankings (correlation coefficient = -0.5741).

15 It should be noted that many domestic degree holders resided abroad in 2006 with temporary positions, such as post-docs or visiting scholars, which can not be viewed as the same as formal research jobs.

Pseudo R^2	0.3875

Note: *p<0.1, **p<0.05, ***p<0.01

The mainstream of return migration to China was negatively selected relative to its scientific diaspora. The propensity to return differed substantially by university ranking among foreign degree holders. The higher the ranking of an emigrant's university of doctorate, the less likely it was that he returned to China for employment by 2006 (Figure 3). Returnees represented over one tenth of foreign degree holders in Class I (11%) and II (13.5%), while they constituted one third of those in Class III (35.5%) and the absolute majority in Class IV (59.1%). Overall, China received one out of five (21.9%) overseas scientists trained abroad by 2006, but most of these returnees (61.2%) graduated from foreign universities ranked below 200 on the 2009 Jiaotong list. In addition, 82.9% of the returnees with foreign degrees were awarded doctorates in the ROW, and only the remaining 17.1% were trained in the USA, the global superpower of science. We may conclude that "the worst of the best" were prone to return to China.

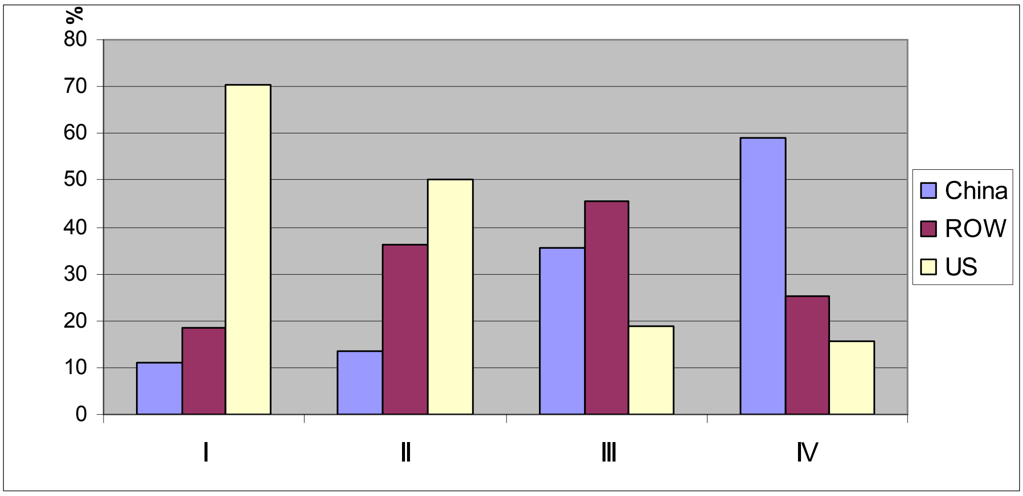

Figure 3 Locations of foreign degree holders in 2006 by class of graduate university

Contrary to our expectation, the negative selectivity of return migration seems to become stronger between 1998 and 2006. The share of graduates from Class I and II among returnee students declines from 56.8% in 1998 to 38.8% in 2006[16] (Table 8). We may speculate that a few outstanding scientists are more likely to move back at the initial stage of the "reverse brain drain", if they can take important positions in their home country. As the national economy grows and research environment improves, more overseas scientists are lured back and the average qualification of returnees decreases with the return tide. Mediocre researchers might have stronger motivations to return than excellent ones, if the former do not foresee a bright future abroad, and try to take advantage of favorable conditions in the home country.

With regard to returnee scholars, the share of graduates from Class III also fell by around 9%

[16] The statistics of 1998 should be interpreted with caution since there are less than ten observations of returnee students in the sample for that year.

during the period, probably because many more domestic scientists visited foreign research institutions over time. As supplementary evidence, the share of Class-III graduates among emigrant scholars also decreased by a similar percentage correspondingly.

Table 8 Class of graduate universities of returnees by year (%)

Year	*Returnee student*			*Returnee scholar*		
	Class I & II	Class III & IV	Total	Class III	Class IV	Total
1998	56.8	43.2	100	76.9	23.1	100
2002	46.0	54.0	100	68.9	31.1	100
2006	38.8	61.2	100	67.4	32.6	100

Note: We exclude returnee scholars who obtained doctorates after the corresponding observation year.

We adopted a logit model to further investigate the effects of different predictors on return migration of foreign degree holders (Table 9). The regression results are largely consistent with the above descriptive analyses. The dependent variable of the model is binary – we coded one's location in China in 2006 as "1", and staying abroad as "0". The sample for the model is confined to foreign degree holders, and the explanatory variables are the same as those in Table 5. Although most odds ratios of the control variables confirm our expectations, they are not statistically significant probably due to the small sample size (N=159).

Table 9 Explaining return migration by 2006

Explanatory Variable	*Odds Ratio*	
Female (vs. Male)	0.270645	
Cohort (Reference group = Pre-incident)		
Early-reform	1.982966	
Post-incident	2.096857	
Millennium	0.873406	
Class of university (Reference group = Class III)		
Class I	0.167559	***
Class II	0.26217	***
Class IV	2.466619	
Field (Reference group= Chemistry)		
Mathematics	1.289872	
Physics	0.897422	
Biology	1.359157	
Observation		159
Pseudo R^2		0.1539

Note: *p<0.1, **p<0.05, ***p<0.01

Males are found to be more likely to return than females; old scientists are more likely to do so than young researchers; so are mathematicians and biologists relative to chemists. These findings are not conclusive since they did not pass the statistical test. Nonetheless, two dummy variables of university class, the variables of our focus, are highly significant. If the reference group is set as graduates from universities in Class III, the odds ratios of return for those in Class I and II were only one fifth or one fourth of that for the reference group. The odds ratio for those in Class IV was almost twice as high as that for Class III, but it is not significant largely due to the small number of observations.

VI Conclusion

This paper focuses on international migration of Chinese scientists between 1998 and 2006. The sample includes 451 individual scientists at leading global universities in English academia. These leading scientists are carriers of cutting-edge knowledge and they make major contributions to the progress of science in China and in their host countries. Their movements between countries influence the construction of top research universities in China, which constitute flagships for the entire national academic system.

To address the first research question, we mapped the geographic distribution of Chinese scientists and identified their migration patterns. The number of scientists in China increased steadily, and the talent pool of overseas Chinese expanded even more rapidly. However, the return rate of foreign degree holders remained at a low level, though the number of returnee students increased dramatically. Meanwhile, many domestic scientists without foreign degrees acquired overseas experience by short-term working or visiting programs, and a majority of them had returned by 2006. Hence the predominant mode of migration in this period was both an ongoing brain drain and an emerging brain circulation. Additionally, we also find considerable differences of migration patterns by cohort and field of study.

We then examined the selectivity of emigration and return flows in terms of educational background. Chinese graduates from colleges in the upper two tiers were far more likely to receive foreign doctoral education than those from the third-tier schools. Moreover, foreign doctoral programs became more selective over time, which confirms our first hypothesis.

The foreign academic markets were also selective, as doctoral graduates from universities with higher rankings had many more chances to work abroad than those from universities with lower rankings. By contrast, negative selection characterized the return migration of foreign degree holders. Contrary to our expectation, the negative selectivity of return migration seemed to become stronger between 1998 and 2006 according to the descriptive analysis.

The results show that China only attracted a few emigrant scientists who graduated from top 200 universities in the world by 2006. China launched several talent programs targeting returnees from the late 1990s, such as the Chunhui Plan, the Yangtze River Scholar Plan, the Hundred Talents Programme, and the National Distinguished Young Scholars Program (Xiang 2003; Zweig 2006). Chinese universities also competed with each other to attract overseas scientists, and provided them with favorable conditions, including suitable working platform, large research funds, free housing, high salary, and other benefits for their dependents. Despite some satisfactory cases, such as the One Hundred Talents Program at CAS (Liu and Zhi 2010), our findings indicate that these programs only achieved limited success in bringing back scientists with higher qualifications by 2006.

In addition, foreign degree holders only represented a small portion (23.1%) of all Chinese returnees at the leading universities in 2006. Although the observations are too limited to provide convincing evidence, at least we did not find that returnee students made an extraordinary contribution to China. Since many returnee scientists who benefited from the programs are actually returnee scholars, China may consider narrowing its focus to outstanding foreign degree holders who have longer working experience in the fields in which China is lagging behind. For example, the current "One Thousand Talent" program has raised the criteria of admission[17].

Favorable conditions for returnees may help lure overseas talent back home, but they may also induce unintended negative consequences in the domestic research system. An influx of returnee

[17] See the program website for the detailed criteria: www.1000plan.org

scientists has considerable impacts on the academic labor market in China, as they compete with stayers for limited positions. China's policy has offered returnees with symbolic and political capital, as "holders of proper western degrees have more human capital, thus more social worth, and in turn deserve special economic and social privileges" (Xiang and Shen 2009).

The social relations between returnees and stayers may generate segmentations in the scientific community in China, if the latter view the former with some suspicion and jealousy, particularly when returnees' contributions do not match their special benefits from the nation. For example, anecdotal evidence suggests that some returnees received higher salaries in China without fulfilling their research responsibilities (Xin 2006). Our data also show that returnees who graduated from lower-class universities were more likely to return to China. If this is the case, then it is not necessary to offer special programs favorable to returnee scientists. A pure merit-based rewarding system would function more effectively and treat members in the Chinese research community equally.

The findings of this study shed light on international migration in the scientific world, and contribute to the rich debate on the issue of brain drain. China's experience reveals that skilled emigration of scientists persists even when some expatriates returned to their country of origin. National strategies targeting the research diaspora can make a limited contribution in luring prominent scholars back home, but a brain circulation can be realized by sending domestic scientists abroad for short-period training or visiting. Future research may focus on the link between knowledge transfer and international mobility, and explore the possibility of "brain gain" without sufficient return migration.

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Appendix I Coding Table of College Degree

Tier	***Frequency***	***University***	
First	2	Peking Univ	Tsinghua Univ
Second	7	Fudan Univ	Nanjing Univ
		Shanghai Jiao Tong Univ	Univ Sci & Tech China
		Xi'an Jiaotong Univ	Zhongshan Univ
		Zhejiang Univ	
Third	13	Beijing Institute of Tech	Beijing Normal Univ
		Beijing Univ of Aero & Astro	Harbin Inst Tech
		Huazhong Univ Sci & Tech	Jilin Univ
		Lanzhou Univ	Nankai Univ
		Shandong Univ	Sichuan Univ
		Tongji Univ	Wuhan Univ
		Xiamen Univ	
Fourth	12	Central South Univ of Tech	China Agr Univ
		Chongqing Univ	Dalian Univ Tech
		East China Univ of Sci and Tech	Hunan Univ
		Nanjing Agr Univ	Nanjing Univ of Aero and Astro
		Northwestern Polytech University	South China Univ of Tech
		Southeast Univ	Tianjin Univ
Total			34

Note: Universities not in the list are categorized into the fourth class.

Appendix II Coding Table of Region

Region	***Province***
Developed region	Beijing, Fujian, Guangdong, Jiangsu, Shandong, Shanghai, Tianjin, Zhejiang
Less developed region	Anhui, Chongqing, Guangxi, Hainan, Hebei, Henan, Heilongjiang, Hubei, Hunan, Jilin, Jiangxi, Liaoning, Shaanxi, Shanxi, Sichuan, Yunnan
Least developed region	Gansu, Guizhou, Inner Mongolia, Ningxia, Qinghai, Tibet, Xinjiang