Economic Incentives and the Quality of Return Migrant Scholars: The Impact of China's Thousand Young Talents Program

Abstract

We study the effect of the Thousand Young Talents Program (*TYTP*) on the academic quality of return migrant scientists to China. Using a unique dataset of hire information in the top Chinese mathematics departments, we find that the program leads to considerable increases in hire quality as measured by educational background and research output. The effects are concentrated in the elite C9 league. However, it appears that research output of previously hired faculty members declined after the introduction of *TYTP* hires, suggesting minimal or negative impact of *TYTP* on faculty colleagues' academic achievements. (JEL *J61, O31, O38, D83*)

Keywords: High-skilled migration, Scientific research, Knowledge spillovers, Public policy

I. Introduction

A strong scientific workforce is the key to driving innovation and long-term economic growth. In the last several decades high-skilled migration has become more frequent. While researchers and policy makers around the globe are increasingly interested in understanding the mobility of the very high skilled, little is known on the pattern and determinants of high skilled migration (Kerr et al, 2016). In the international flow of talents, it has been well-documented that developing countries tend to experience large scientific brain drains to developed countries (Weinberg, 2011; Docquier and Rapoport, 2012). In recent years, many countries have initiated programs to attract talents abroad to return to their home country.[1] However, there is little empirical evidence on the effectiveness of such programs on the quantity and quality of return migrant scholars and the impacts of the inflow of high-skilled returnees on the productivity of homegrown scholars.

In this paper, we fill in this gap and report the impact of China's Thousand Young Talents Program on the return of young overseas scholars to highly ranked academic positions in China, their home country. China has become a major source country for scientists in the global talent flows during the 2000s, with the U.S. as the main destination country (Freeman and Huang, 2015). Previous studies find that many Chinese students who earned PhDs in the U.S. stay in the U.S. after graduation, accounting for a disproportionally large proportion of the science and engineering (S&E) workforce in the U.S. (Grogger and Hanson, 2015; Finn and Pennington, 2018). For many years China adopted an open talent policy: encouraging students to

[1] Examples in developing countries include the Young Talent Scholarship and the Special Visiting Researcher scholarship in Brazil and the Project 5-100 in Russia. Examples in developed countries include the World Class University Project in South Korea, the Canada Research Chairs Program in Canada, and the Consolidator Grants and Advanced Grant in the European Union.

go abroad and to return. More recently, the Chinese government has initiated policies to attract and retain overseas high skilled individuals. In 2008, the 1000 Talents Program was launched to attract leading researchers abroad to come back and participate in R&D in China.[2] The expansion of the 1000 Talents Program to new PhDs in 2011 marked a major increase in its scope and funding. The newer program, the Thousand Young Talents Program (*TYTP*), aims to attract rising stars under age 40 who obtained PhD degrees from prestigious universities abroad and have three-year overseas research experiences in S&E. The program provides strong incentives including generous research support to awardees who return to work full time in China.[3]

Based on department records and individuals' curricula vitae (CV), we construct a unique dataset of new hires in the top-20 mathematics departments in China from 2000 to 2017. We also construct complete publication profiles for individual scholar in departments in the elite C9 League using data from Scopus. Using an event-study research design, we find that *TYTP* has achieved considerable success as measured by the increase in the number of jobs filled by young scholars with PhD degrees earned from top-ranked overseas institutions. The proportion of new hires with their PhD degree from a top-50 mathematics department abroad increased by over 10 percent at the top-20 institutions in China after the opening of *TYTP* in 2011. However, there is evidence that these institutions have been marginally less likely to hire new faculty from worldwide top-50 mathematics departments located in China after *TYTP*, suggesting possible crowding-out effects on domestic researchers. Second, we show that the increase in hire quality is not evenly distributed across institutions. Our results indicate that newly hired *TYTP*

[2] https://en.wikipedia.org/wiki/Thousand_Talents_Program. While the program has no restrictions on nationality, the majority of *TYTP* scholars are Chinese.
[3] The *TYTP* award from the central government includes a one-time bonus, research funding, and housing assistance. Additional funding from the local government usually matches that from the central government.

mathematicians are concentrated in departments in the top tier—those in the Project 985 C9 League.[4] Estimates conservatively indicate a doubling in the proportion of new hires with PhDs from top-50 mathematics departments outside China in the C9 League. Moreover, there is evidence that under *TYTP*, top-level departments in the East- and Central regions have experienced increased success in hiring graduates from highly ranked PhD programs relative to departments located in the less favored Northeast- and West regions. The results are very robust to the inclusion of institution fixed effects, a rich set of timing varying characteristics, and region-specific trends.

Next, along with the large inflow of returnees from worldwide top departments, we find that departments in the C9 League experience significant increases in the quality of pre-hire publication achievements for new hires as measured by (i) the growth in the number of publications of these new hires prior to their return; and (ii) the quality of these publications as measured by citations by other scholars in their published work. Results suggest that weighted pre-hire publications increased by about one-fourth, while citations to pre-hire publications increased by more than one-third after the opening of *TYTP*. Lastly, while our measures of the education backgrounds and scholarly productivity of new hires indicate a positive impact of *TYTP*, it is also important to assess whether programs that aim to bring talented researchers together lead to an increase in research output of non-*TYTP* scholars that would not have occurred in the program's absence. To explore such spillover effects, we adopt a difference-in-difference research design using annual publication data for each scholar in departments in the C9 League who were hired before the initiation of *TYTP*. Exploiting the regional variation in the distribution of *TYTP* awards, we find that the introduction of *TYTP* hires is associated negatively

[4] https://en.wikipedia.org/wiki/C9_League

with the research output of their colleagues who were hired before *TYTP*. Both weighted-publication and citation measures were about 15% lower among the faculty exposed to the inflow of *TYTP* scholars than among their counterparts who were not exposed. We further demonstrate that the decline seems to be associated with the lower frequency of coauthorship between existing hires and the new *TYTP* hires.

Our investigation relates to the growing literature surrounding the determinants of scientists' mobility. For example. Gibson and McKenzie (2011) find that the return migration decision among the very high skilled is strongly related to family and lifestyle reasons rather than difference in cross-country income opportunities. On the other hand, Gaulé (2014) studies the return migration decisions of foreign faculty based in United States chemistry departments and reports a high degree of responsiveness to economic conditions in the home country. Results also indicate that new PhDs and young faculty are the most likely to take advantage of opportunities to return to their home countries. Similarly, Grogger and Hanson (2015) analyze the location decisions of foreign-born Science and Engineering PhDs in the United States and find that intend-to-stay rates are strongly correlated with economic growth rates. Moreover, the authors find that stay rates among Chinese degree recipients have been declining in the 2000s[5], which they conjecture is in response to the rapid economic growth in their home country. Akcigit, Baslandze, and Stantcheva (2016) demonstrate that top tax rates significantly affect international mobility patterns of superstar inventors. Moretti and Wilson (2017) show that interregional tax rates are important in determining the location decisions of "star scientists" and, presumably, other high-skilled workers. Our results demonstrate that the initiation of *TYTP* grants leads to significant increases in the proportion of new hires with PhDs obtained from top

[5] See Figure 5 in their paper. Their analysis uses data from the Survey of Earned Doctorates through 2008.

overseas institutions and that the effects remain large and statistically significant after accounting for other factors that might affect mobility including economic growth and improved research environment in the home country. We take this as consistent with the importance of the financial incentives in migration decisions among the very high skilled.

We also add to the handful of articles on the spillover effects of high skilled migrants. Hunt and Gauthier-Loiselle (2010) find that in the U.S. the patenting rate among immigrants is double that of natives, primarily due to their concentration in Science and Engineering fields. Employing an aggregative approach using 1940-2000 state data on immigrant college graduates, the authors examine spillovers from scientifically trained immigrants to domestic innovation, identifying a positive relationship between the share of skilled immigrants and per-capita patents. Kerr and Lincoln (2010) find that higher H-1B admissions in the U.S. lead to substantial increases in immigrants' S&E employment and patenting by immigrants from India and China. However, the authors find few spillover effects on natives and suggest that immigrants boost innovation largely through their direct contribution. Borjas and Doran (2012) study the emigration of mathematicians following the 1992 political revolution in the Soviet Union to identify spillover effects. They find that the influx of Soviet mathematicians negatively impacted the research output of American mathematicians in overlapping areas.

We approach the issue of human capital spillovers from migrant scholars to their colleagues using the variation in exposure to *TYTP* hires. The large inflow of migrant scholars induced by the *TYTP* grants, combined with the fact that returnees tend to locate in the Coastal regions holding the quality of hiring department constant, provides variation in our sample that permits employing our difference-in-differences framework. We find statistically robust and quantitatively significant *negative* relationships between the treatment spillovers of *TYTP* on

both weighted-publication and citation production of pre-*TYTP* hires. We further demonstrate that these impacts are supported by evidence of a lack of co-authorship between returnees and existing faculty. We infer that policies that facilitate collaboration between returnees and domestic colleagues could magnify the positive impact of return scholars on host countries' research. We believe that our focus on *TYTP* grants in China, yields results that are relevant for other developing countries as they seek to turn brain drains into brain gains in the global flow of talents. One important implication from the findings is that incorporating strong financial incentives, along with generous research support, in talent policies can play a crucial role in attracting and retaining overseas talents.

The rest of the paper proceeds as follows. Section II describes our data and sample construction; Section III presents our methodology for analyzing the impact of *TYTP* on new hires; Section IV reports our estimation results; Section V presents methodology and empirical results for analyzing spillover effects; Section VI concludes.

II. Data and Sample Construction

We obtain data on the academic background and subsequent professional progress of new hires from the 24 mathematics departments ranked in the top 20 (including ties) in China[6] between 2000 and 2017. We limit the sample to the top 20 departments as return scholars with PhDs from top overseas institutions have been unlikely to choose lower ranked departments.[7] The full list of the hiring departments is reported in table 2. We choose the field of mathematics

[6] http://www.cdgdc.edu.cn/xwyyjsjyxx/xxsbdxz/2012en/index.shtml#. There are 4 departments tied in the same rank.

[7] We show later that within the top 20 department the increases are concentrated in the C9 league.

for this phase of our study, because it plays a foundational role in scientific research. Moreover, mathematicians' research output is relatively well identified in publication records.[8] Using a list of current faculty members from department websites, we collect information on date of hire, whether the new faculty was hired under the *TYTP* program, the hire's educational background, and academic experience from each faculty member's CV, personal web page, and other sources that may be available on the internet. Using data from Scopus,[9] we also construct a sample of complete publication profiles for new hires from the mathematics departments in the Project 985 C9 subset[10] of these departments during the sample period.

Our three measures of hire quality are: (i) the international ranking of a returnee's PhD-granting department, (ii) the number of publications before hire inversely weighted by number of authors, and (iii) the number of citations to the publications inversely weighted by years since publication and number of authors. In addition to information on a new hire's *TYTP* status and "quality" as described above, we obtain the following variables in order to obtain unbiased estimates of the impact of *TYTP*: (i) undergraduate institution and (ii) post-doctoral institution if any, and years of post-doctoral training. The sample for analysis is trimmed of observations with insufficient data for our estimation exercises by dropping observations with missing information on these key variables. Our total sample consists of 953 new mathematics-department faculty hires over the 2000-2017 period. *TYTP* awardees account for 74, approximately 20.2% of the 365 faculty hired after 2010. Although we are unable to obtain complete information for all new hires in all departments in our sample, we find no appreciable correlation between sample completeness and universities' quality ranking.

[8] There are a number of discipline-specific studies of aspects of international migration of scholars. See Hunter, Oswald, and Charlton (2009), McDowell and Singell (2000), Albarran, Carrasco, and Ruiz-Castillo (2017) etc.
[9] https://www.scopus.com/search/form.uri?display=basic
[10] https://en.wikipedia.org/wiki/Project_985.

Graduate Education of New Hires. Summary measures of graduate education background for all new hires in the 24 top 20 mathematics programs over the pre-*TYTP* subperiod 2000-2010 and 2011-2017 are reported in table 1. We focus on the proportions of new hires who obtained their PhD degree from mathematics departments ranked in the top-50 worldwide and their subsets inside and outside of China. The first row reveals a substantial increase in the proportion of new hires who obtained their PhD degrees from top-50 departments, and the proportion who graduated from top-50 departments outside China (which is a prime focus of *TYTP*) nearly tripled. At the same time, the proportion of new hires with PhDs from top-50 departments located inside China fell slightly from 17.2% to 15.6%. We note that the standard deviations of the top-50 hire ratios are quite large relative to their means, and the heterogeneity of *TYTP* impacts across our sample institutions is an important focus of our analysis.

Examining the hiring experience of the C9 subgroup of mathematics departments, we see in table 1 that prior to 2011, approximately 7.4% of C9 departments' new hires received PhD degrees from top-50 departments located outside China—about 2.4 percentage points more than those hired by the departments not included in this most elite group. Under the *TYTP* program, the C9 group's top-50 abroad hire ratio nearly quadrupled, while the remainder of our sampled departments' ratio of these hires rose to approximately 1.5 times its level prior to 2011.

Publications and Citations of New Hires: C9 Departments. We obtain information on publications and citations as perhaps more compelling evidence of professional quality than the education background of new hires. Our publication-based measures of hire quality are based on a sample of faculty newly hired by mathematics departments in the C9 League between 2000 and

2017. [11] To acquire the volume of data needed for this phase of our study we have limited our analysis to the 7 C9 departments for which sufficient information is available to us. The universities are Peking University, University of Science and Technology of China, Tsinghua University, Zhejiang University, Xi'an Jiaotong University, Shanghai Jiaotong University, and Harbin Institute of Technology.[12]

We also collect each hire's s complete publication data including publication year, journal name, number of authors, number of citations, and author affiliation. We identify 6,299 articles published by the 296 hires in our sample. From our initial sample we obtain two measures of pre-hire hire quality for each individual: (i) 1889 articles published before hire or within two years after hire, as these are most likely to have been completed before hire, and (ii) total citations to these articles. In order to approximately link an article to the time in which it was written, it is assigned to 2 years prior to year of publication. For example, for someone hired in the year 2010, articles published through the year 2011 are assigned to the faculty member's pre-hire period. As noted in table 1a, publications are weighted by the reciprocal of the number of authors, e.g, an article with 2 authors receives half the weight of an article of which the faculty member is the sole author. Citations are similarly lagged and inversely weighted by number of authors. Further, to approximately account for the time path of citations—it takes time for an article to be read, noted, and cited in another publication—we divide a faculty member's accumulated citations through the year (t) when citations are counted by (1+(t-year published)). For example, citations counted in 2018 to a solely authored article published in the year 2010

[11] Data suggest that the C9 institutions receive disproportionately large amount of the nation's research funding. Researchers at the C9 institutions, while representing 3% of all researchers in the country, contribute to over 20% of total publications and 30% of highly cited papers.

[12] We have information on the key variables for over 40 percent of all faculty members in the 7 departments. In the remaining 2 departments at Fudan University and Nanjing University, there is limited faculty information from the department websites and the majority of faculty members do not have a personal webpage.

would be divided by (1+(2018-2010) = 9), while accumulated citations to a solely authored article published in the year 2009 would be divided by (1+(2018-2009) = 10).

Table 1a reports summary statistics for the 7 C9 departments in the analysis sample. There are striking changes in output measures of the quality of hires after the initiation of *TYTP* in 2011. The weighted publication-based indices of newly hired junior faculty quality increased approximately 1.25 times, from 2.79 in the period 2000-2010 to 3.50 in the period 2011-2017. The weighted citations increased 1.5 times, from 2.81 to 4.31 following the initiation of *TYTP*. We note that standard deviations are quite high relative to means, suggesting substantial dispersion of these measures over individual new faculty members. Summary statistics of publications and citations are reported separately in table 1a for the 5 of our sampled C9 departments that successfully hired *TYTP* scholars before the year 2016 (thus allowing us to attribute publications and citations through the year 2017) and for the 2 C9 mathematics departments that did not. Although these 2 departments hired far fewer new faculty whose PhD degrees were obtained from overseas top-50 graduate institutions, weighted publications before hire increased by a far greater proportion for their new hires in the 2011-2017 period than did those hired by the other 5 departments. Even more striking is that in 2011-2017, cumulated weighted citations during the *TYTP* period for new hires in these 2 departments exceed those in the other 5. Again, we recognize that the standard deviations of these summary statistics are very high relative to their means, implying that further analysis on research performance among hires in the 2011-2017 period is warranted.

III. Methodology: Quality of New Hires

We introduce our estimation strategy for assessing the impact of *TYTP* on the quality of new hires with the following equation:

$$Hire_{ict} = \beta_0 + \sum \beta_t year_{ict} + \varepsilon_{ict} \quad (1).$$

The dependent variable is a measure of quality of hire *i* at institution *c* in year *t*, and quality is defined as (i) a dummy variable equal one if the new faculty received his/her PhD degree in a non-Chinese institution ranked among the top-50 departments worldwide, (ii) a measure of publication success prior to hire, or (iii) a measure of citations to publications attributable to pre-hire activity. We first regress a quality measure on a set of year dummies from 2000 to 2017, with year 2010 omitted as the base year. Thus, for quality measure (i) each of the year coefficients reflects the share of hires from top-50 departments abroad in that year relative to that in 2010, the base year.

Estimation of equation (1) may be biased due to omission of confounding variables, for example, government directives and budget reallocations increasing salaries and benefits, increased quality standards for non-*TYTP* hires, and possibly increased competitive pressures. To control for such omissions, we conduct an event study analysis as specified in the following equation:

$$Hire_{ict} = \alpha + \beta * TYTP_t + \gamma x_{ic} + \varepsilon_{ict} \quad (2).$$

The outcome variable is a measure of hire quality as defined for equation (1),[13] *TYTP* is a dummy variable equal to one if a faculty member was hired from the first year of *TYTP* awards, 2011, through the end of our sample period, 2017, and zero otherwise. The vector *X* is a set of institution level control variables, including institution quality measured by discipline ranking, dummy variables indicating a member of the C9 League, a Project 985 university, and location of the hiring institution. Note that the C9 institutions are a subsample of the Project 985 institutions.

The identification assumption of equation (2) is that absent *TYTP*, the trend in the measure of hire quality would have been the same in the post-policy years as it was in the earlier years. Under this assumption, the coefficient of *TYTP* represents the effect of the program on the quality of new hires. We view this assumption as valid since to our knowledge there was no other national policy targeted at attracting overseas talents at the junior level implemented during our sample period.[14] To address the possible omission of other time-varying factors affecting hire quality, e.g., rapid economic growth in China might have attracted more overseas talents as noted in our literature survey above,[15] we conduct robustness checks by sequentially including the following variables in estimation of equation (2).

1. GDP growth averaged over three years prior to the hire year is included to account for the impact of economic conditions on hire quality.[16]

[13] We have considered several other measures, including receiving PhD from rank top-100 and top-200 overseas department, as well as from any top ranking departments. Results are robust to these alternatives.
[14] The universities in the sample are national universities and receive funding from the Ministry of Education of the People's Republic of China.
[15] Grogger and Hanson (2015).
[16] Data calculated based on the World Development Indicators by the World Bank (http://datatopics.worldbank.org/world-development-indicators/).
We also consider other measures for economic growth, including GDP growth in the previous year, GDP per capita growth in the previous year, and GDP per capita growth in the previous three years. Estimation results are robust to the use of these alternative measures.

2. A measure of the growth in total number of publications in science and engineering produced in China using data obtained from Scopus[17] is added to control for the general growth in science and engineering publication in China. These publications have increased considerably since the early 2000's. This growth could increase the appeal of joining a Chinese faculty and thus have a positive impact on the quality of applicants. It could also lead the top universities to raise their hiring requirements implicitly or explicitly.
3. As the number of Chinese students and scholars studying and visiting abroad has grown over the years, one might expect to see the number of high-quality returnees increase. We thus include the annual growth rate of the number of Chinese students and scholars abroad to account for these supply side factors.[18]
4. Annual R&D funding data is added to capture time varying characteristics in hiring institutions' research environment.[19]
5. As a further robustness check, we add a region-specific linear trend, T, to control for any underlying trend at the local level.[20]

The fully modified specification is:

[17] The publication data collected from the Science & Engineering Indicators 2018 by National Science Board (https://www.nsf.gov/statistics/2018/nsb20181/) and Scimago Journal & Country Rank (SJR) website (https://www.scimagojr.com/countryrank.php) powered by Scopus.
[18] The number of individuals studying overseas each year is published by Ministry of Education of the People's Republic of China (http://en.moe.gov.cn/documents/statistics/2018/national/, more information on the Chinese website). This covers students at all levels and includes postdoctoral researchers and visiting scholars.
[19] Data collected from China Statistical Yearbook, annual series published by Ministry of Education of the People's Republic of China.
[20] Estimation results, not reported here, are robust to alternative non-linear trend specifications at the national and province levels. We also estimated regressions containing a pre-event linear trend = 1 through the year 2010, =0 for years 2011-2017, to account for any variables that might have affected the pre-*TYTP* measures of hire quality relative to those observed after the year 2010. Estimation results indicating strong rejection of the null hypothesis of no *TYTP* effect are quite robust to inclusion of the pre-trend variable.

$$Hire_{ict} = \alpha + \beta * TYTP_t + \gamma x_{ic} + \phi z_t + \delta T_{rt} + \varepsilon_{ict} \quad (3)$$

where the vector *z* represents controls for time-varying factors including GDP growth, growth of the number of publications in science and engineering, growth of the number of Chinese students and scholars abroad, and R&D funding; *T* controls for region-specific trend, as defined above.

It is reasonable to hypothesize that a talented scholar with PhD degree from one of the world's most prestigious institutions would more likely accept an offer from a department in a C9 league-ranked university than one containing similar benefits from an institution not included in this prestigious group. Joining a C9 department would allow the new faculty member to share the institution's higher reputation and to benefit from a presumably more fertile academic environment, given equal salary and research funding. As reported in the summary statistics of table 1, C9 institutions have enjoyed a substantially larger increase in the proportion of faculty from top departments abroad than did the remaining 24 top institutions. To capture the differential effects of *TYTP* on the quality of hires between departments in the C9 institutions and those in the remaining top- 20 institutions, we expand equation (3) to:

$$Hire_{ict} = \alpha + \beta_1 * TYTP_{ict} + \beta_2 * TYTP_{ict} * C9_{ict} + \beta_3 * C9_{ict} + \gamma x_{ict} + \phi z_t + \delta_p T_{rt} + \varepsilon_{ict} \quad (4)$$

where the variable *C9* = 1 for institutions included in the *C9* league, = 0 for the remaining top-20 institutions.[21]

[21] The specification also includes control variables similar to those included in estimation of equation (3). Estimation results are robust to inclusion of year- and institution fixed-effect dummy variables. We also estimate probit regressions and find robust results.

IV. Estimation Results

We report results for equation (1) both graphically and in tabular form. Figure 1 provides a simple summary of the relation between initiation of *TYTP* and quality of non-foreign new faculty hired by the 24 mathematics departments ranked among the top 20 in China over the period 2000-2017. The quality of the newly hired faculty is defined as in equation (1), where the dependent variable equals 1 if their PhD degree was obtained from an institution whose mathematics department is ranked among the top-50 worldwide and is located in an institution outside China. The year 2010, one year prior to the initiation of *TYTP*, is the base year, omitted from the regression; thus figure 1 plots the coefficients showing the deviation of the quality-of-hire measure from its 2010 value. Values are clearly negative on average prior to 2010 and on average greater than zero after 2010. Moreover, after 2010, the series exhibits a rising trend, compared to approximately flat in prior years. The impact of *TYTP* on hire quality illustrated in figure 1 reflects the summary statistics reported in table 1, where we see that the proportion of non-foreign hires in the top-20 mathematics departments who received their PhD degrees from overseas departments among the worldwide top-50 increased from 5.8 percent over 2000-2010 to 16.2 percent over 2011-2017.

As noted above, the benefits of *TYTP* have been unequally distributed among China's top-20 mathematics departments, with those in the elite C9 league attracting the lion's share of hires from top-50 departments located outside China. Figure 2 illustrates graphically the hiring advantage of C9 institutions over the remaining institutions in the top-20 group. It is clear that the trends in hiring new faculty from overseas top-50 departments were similar for the C9 and non-C9 institutions prior to the year 2010 and that the positive impact of *TYTP* on hire quality has been concentrated among departments in C9 institutions. The patterns illustrated in figure 2

are consistent with the sample means reported in table 1. Departments in the C9 group increased the proportion of their hires from top-50 overseas PhD programs approximately 4-fold to almost 30 percent over the period in which the *TYTP* funding became active, while the proportion of comparable hires in the remaining departments in the top-20 rose from approximately 5 percent to 7.4 percent.

In equations (2) - (4) we expand the benchmark model in which a measure of hire quality is regressed on a dummy variable, *TYTP,* =0 prior to the year 2011, = 1 in years 2011-2017. The aims are (i) to assess the impact of *TYTP* on alternative measures of the quality of new hires, (ii) to control for omitted-variable biases and (iii) to identify differential impacts of *TYTP* on the quality of hires across institutions according to their ranks among China's top-20 mathematics department. In table 3 we report estimation results introducing control variables sequentially following the *TYTP* dummy. The estimated coefficient of *TYTP* alone on the number of non-foreign hires reported in column (1) 0.104, plus the constant term 0.058, is highly significant and equals .162, the mean proportion of new hires from top-50 abroad institutions after initiation of *TYTP* shown in table 1. Columns (2)-(8) all include region dummy variables as defined in the table notes. Column (3) includes additional variables to control for differential experience among hiring departments according to their institutional ranking and inclusion in the elite 985 and/or C9 groups. In columns (4) through (7) we add national time-varying factors which possibly influence the ability of departments to hire quality faculty members who have received their graduate education overseas. Finally, regional trend variables are included in column (8) to account for any remaining changes at the local level that might affect hire quality.

We focus on the estimated coefficient of *TYTP*, which is highly robust in magnitude and significance, in the range of 0.1, approximately equal to the difference in the proportion of new

hires with PhD degrees from the top-50 abroad institution after and before the advent of the *TYTP* program as shown in Table 1 for all top-20 departments. In column (8), where the regression includes the regional trend variable, the coefficient of *TYTP* suggests that the top mathematics departments in China increased their proportion of new hires from top-50 overseas institutions by 11.6 percent after the initiation of *TYTP*.[22]

Heterogeneous Effects between C9 Institutions and non-C9 Institutions. Regression results based on equation (4), where the variable *TYTP* is interacted with institutional membership in the C9 League, are reported in table 4. The sum of the constant term and regression coefficients in column (1) equals 0.291, the proportion of new hires with PhD degrees from top-50 overseas institutions, as indicated in Table 1 for C9 institutions after the initiation of *TYTP*. The coefficient of the stand-alone variable C9 in column (1) is highly insignificant, implying, consistent with the results illustrated in figures 2, that there was little difference in junior hires from top-50 overseas mathematics departments between C9- and the remaining top-20 institutions prior to 2011. However, after initiation of *TYTP*, C9-league institutions increased hires of new PhDs from top-50 overseas institutions by an average of 20 percent compared to a negligible impact for the others in the top 20.[23] Column (2) to (8) suggest that these estimates are quite robust to inclusion of institution rank and inclusion in the select Project 985 subset of top-20 institutions and to all of the additional controls reported in table 3. The coefficients of the control variables reveal considerable region variation in hire quality. Estimates in column 2 of table 3 and 4 suggest that institutions located in the West and Northeast regions are significantly less likely to hire new faculty from top-50 departments abroad compared to those in the East

[22] Probit estimation suggests a marginal effect of 8.93 percent increase at the mean.
[23] The marginal effects estimated from probit regressions are similar, indicating an increase of 20.37 percent at the mean for the C9-league institutions and no perceptible changes for the others.

region, whereas there appears to be little difference in hiring experience between institutions in the Central region and the East region. The estimates also confirm that the quality of the hiring institution, reflected in its inclusion in the 985 and/or C9 groups, is an important determinant of hire quality. Further, the coefficients for the lag growth rate of the total number of students and scholars abroad are positive and statistically significant, implying the role of supply shifts on hire quality.

Publications and Citations of New Hires in C9 Institutions. Admission to, and obtaining a PhD degree from, a highly ranked institution is surely a marker of the quality of newly-hired faculty. However, this measure of quality is only a predictor of a scholar's contribution to their discipline. To more thoroughly establish the impact of *TYTP* on the quality of hires in China we explore (i) number of publications in professional journals and (ii) citations to these publications. As noted above, we weight these measures for coauthorship, dividing by the number of authors and we further weight citations, dividing by years since publication to allow for the lag between an article's first published appearance and its citation.[24]

We first obtain an overview of the time path of hire quality by estimating:

$$\log Pub_{ict} = \beta_0 + \sum \beta_t year_{ict} + \varepsilon_{ict} \qquad (5)$$

which replicates equation (1), replacing the dependent variable with a log-measure of hire quality, number of publications and or number of citations, weighted by years since publication

[24] Galiani and Gálvez (2017) examine the life-cycle pattern of citations.

and number of authors as described above. We then proceed similarly as we do with equation (3), adding controls for possible biasing omitted variables.

We illustrate the regression results for equation (5), along with the 95% confidence interval for (i) weighted number of publications in figure 3 and (ii) weighted citations in figures 4 and 5. Estimated regression results based on equations (2) and (3) are reported in tables 5-6. The pre- and post-2010 time patterns of both the weighted publications- and weighted citations series are similar to those for the hires series reported in figure 1—averaging negligible deviations from 2010 prior to *TYTP* and positively deviating from 2010 afterward. To illustrate this break more clearly, we estimate equation (5) for log of weighted citations, without a constant term and including dummy variables for each year 2000-2017, reporting the estimated coefficients for each year in figure 5. We separate the results into two charts and fit a linear trend to each series. The notable jump between 2010 and 2011 is reflected in the constant term of the post-2010 trend equation nearly doubling from its value in the pre-2011 series. The trend slopes are approximately equal—0.044 log weighted citations per year prior to 2011 and 0.046 after 2010.

In tables 5 and 6, column (1) reports estimation results of regressions including only the dummy variable *After* equal to 1 for years 2011-2017. The estimated coefficient of *After* indicates an approximate 24 point increase in log weighted publications (27 percent increase) and nearly 42 point (49 percent) increase in log weighted citations following initiation of *TYTP* (both figures approximately equal to the proportionate increase in the mean values reported in table 1a). Results reported in columns (2)-(7) of tables 5 and 6 test the robustness of estimated responses of these weighted publications and citations, respectively, to *TYTP* when we successively add variables reflecting (i), the hiring department's ranking within China's

mathematics departments and its regional location, (ii) recent GDP growth, (iii) recent growth of published scientific and engineering articles in China, (iv) growth in the number of Chinese students studying abroad, (v) recent growth in science and engineering funding, and (vi) region linear trend as described above. The estimation results for both publication-based measures of the impact of *TYTP* on the quality of new hires are very robust to the inclusion of omitted and possibly confounding variables and are generally greater in magnitude than its value for *TYTP* standing alone in column (1).

V. Are There Spillover Benefits of *TYTP*?

All evidence indicates that the *TYTP* initiative led to marked increases in direct measures of the quality of mathematics-department junior hires in top-20 universities particularly in their C9 subset in China. While some policy makers may find that these measures of success constitute sufficient benefits relative to their costs to China, others might question *TYTP*'s value as measured by the program's contribution to the progress of innovation and advancement of knowledge. As noted above in connection with the migration of Russian mathematicians, relocation may have a negative productivity impact on those working on similar topics in migrants' destinations. The possibility of negative spillovers to existing faculty in China working in competing fields leads us to inquire whether or not the introduction of returned scholars generates observable spillovers to the productivity of those existing faculty that would not have occurred in the absence of *TYTP*. Alternatively, funds expended on salaries and amenities for *TYTP* beneficiaries might have been allocated, for example, to finance research programs for domestic mathematicians and expanded education opportunities at various levels. We do not speculate on the magnitude of benefits that might have accrued to such alternative expenditure

patterns, but we can attempt to measure, at least crudely, the short-term benefits of *TYTP* as measured by the creativity of non-*TYTP* mathematicians in China that are attributable to their association with returned junior *TYTP* scholars. We thus proceed from our evaluation of the publication and citation evidence for the quality of junior hires attributable to *TYTP* to investigate measures of their influence on the research of their colleagues who were hired prior to *TYTP* and who might be expected to have been affected by the introduction of their well-credentialed new colleagues.

Data and Sample. We explore the potential spillover effects among faculty in departments in the C9 sample, because *TYTP* grants have been predominately awarded to institutions in this elite league, as confirmed in the results reported above, whereas the other top 20 departments had little change in hire quality. Within the C9 league, we focus on learning how after-hire research output of the junior faculty who joined the mathematics departments between 2000 and 2010 has changed after being exposed to the *TYTP* hires. Non-*TYTP* hires who joined the departments after 2011 are not included in this analysis since most of their publications after-hire are potentially affected by *TYTP* hires, thus precluding difference-in-difference analysis.

Summary statistics are reported in table 7 and cover the same departments as in our preceding investigation of the publications and citations of new hires. For each of the 172 junior faculty members, we collect complete publication data from the date of their first article through the year 2017 from Scopus.[25] We categorize the articles of an individual researcher by year of publication and construct two variables to measure the scientific output in each year: (i) number of publications and (ii) number of citations to these publications at the time of data collection.

[25] Data were available for years 2018 and 2019, but we thus did not include publications in these two years as they might be incomplete.

Both measures are weighted, as above, by the number of authors, and the citations measures are further divided by year since publication. The total number of weighted publications is 2616.[26]

We focus on the relationship between *TYTP* and pre-*TYTP* hires' articles published two years after the author joined the current department. Articles published before hire and those published within two years of hire are considered as work done during graduate school or postdoctoral training. In order to clearly mark the point at which the impact of *TYTP* hires on their colleagues' research can be evaluated, we thus limit our Analysis Sample (separately designated in table 7) to publications of faculty members who were hired between 2000 and 2009, two years prior to the hiring of *TYTP* faculty, given our assumption of a two-year publication lag.[27] In some specifications, we use publications before hire to account for heterogeneity in hire quality. The Analysis Sample consists of a panel with 1612 author-weighted publications summed over individual researchers and publication years.[28] The average number of weighted publications per individual after hire is 0.787 per year and the average number of weighted number of citations is 0.844 per year. The annual average weighted publications and citations were respectively 0.769 and 0.864 per individual between 2002 and 2012, and they equaled 0.803 and 0.826, respectively, after the introduction of *TYTP*.

In total, *TYTP* awardees account for 46, approximately 36%, of the 127 faculty hired after 2010 by the mathematics departments in the analysis sample. However, there is substantial variation in the distribution of the awards within this elite league. Notably, the awards are concentrated in the five mathematics departments where approximately 48.4% of hires between 2011 and 2017 are *TYTP* scholars. By contrast, the remaining two departments received no *TYTP*

[26] We focus on publications in professional journals and do not include conference proceedings. The total number of (unweighted) publications is 4131.
[27] Results are robust to including the 2010 hires.
[28] The total number of publications is 3126.

junior faculty until the year 2016. The uneven distribution of *TYTP* awardees within C9 league may appear surprising, given that they are the elite institutions in China. To our knowledge, the program sets no institution-based quota for *TYTP* offers. The award decision is mostly based on applicants' qualifications.[29] We conjecture that the small number of *TYTP* scholars at the two institutions is due to applicant preferences for favored location in the central and coastal provinces, where the five institutions are located. As seen in table 1a, the five departments appear to have been favored by potential hires with a PhD degree from a top-50 institution abroad before the implementation of *TYTP* as well as in the sample years after *TYTP* grants initiated.

As indicated in table 7, we designate the cohort of faculty hired between 2000 and 2009 in the two mathematics departments that hired no *TYTP* junior faculty before the year 2016 as "Non-Treated" by *TYTP* and those in the remaining five as "Treated" by *TYTP*.[30] Interestingly, while weighted publications per individual faculty member in the non-treated C9 mathematics departments were barely half and weighted citations less than one-third those of faculty in the treated group prior to inauguration of *TYTP*, they reached approximately 80% of the weighted publications and citations of the Treated-group faculty after the introduction of *TYTP.* Moreover, neither quality measure for 2000-2009 cohort faculty in the treated group is higher in the presence of *TYTP* than in the preceding period, suggesting further investigation of possible lack of positive spillovers from *TYTP* hires to those in the 2000-2009 cohort faculty.

[29] Institutions with key disciplines and national key labs might have an advantage in receiving the award. There is less variation in this aspect for the C9 sample.

[30] The five departments in the East and Central regions collectively received 44 *TYTP* scholars, approximately 95.7% of awardees in the sample. By contrast, the two departments in the West and Northeast did not hire any *TYTP* scholars till 2016. Harbin Institute of Technology hired one *TYTP* scholar in each year 2016 and 2017. Xi'an Jiaotong University had one *TYTP* hire in 2016. These *TYTP* hires are likely to be too recent to affect output of the existing hires in our sample.

Estimation Strategy. In order to more formally assess the impact of *TYTP* faculty on the research productivity of their colleagues, we take advantage of the uneven allocation of *TYTP* awards across C9 institutions discussed above to estimate the benefits of having *TYTP* colleagues. To assess the impact of *TYTP* colleagues on 2000-2009 faculty productivity, we adopt a difference-in-difference strategy, specifying the equation:

$$Publication_{ict} = \alpha + \beta_1 * TYTP_{ict} * Treat + \delta Year_t + \varphi Inst_c + \varepsilon_{ict} \quad (6)$$

where, as above, the outcome variable is the log of scientific output of faculty member *i* at institution *c* in year *t*, and as in preceding equations, *TYTP* is a dummy variable indicating the initiation of the program equal to one if the outcome variable is observed in any year between 2011 and 2017, equal to zero otherwise. The variable *Treat* indicates treatment status and equals one if the publication is produced by a researcher at one of the five institutions that experienced a large increase in *TYTP* scholars after the program began and equals zero if the publication is authored by a researcher at one of the remaining two C9s. The coefficient of interest in equation (7) is β_1. Assuming that the trend in research output of faculty members at the treated departments would have been the same as that at the non-treated departments in the absence of *TYTP*, the coefficient β_1 captures the spillover effects of *TYTP* hires on the scientific output of the previously hired faculty members as defined above.

Figure 6 compares the departmental average number of academic publications in mathematics produced by faculty in departments that received the majority of *TYTP* hires (treated departments) and the number in the remaining (non-treated) two departments. Notably, while the average departmental output of the treated departments is higher than that of the non-

treated, the trends are similar between 2000 and 2010. In addition to aggregate (department-average) trends in publications and citations of faculty hired prior to *TYTP*, we explore trends in weighted publications/citations at the individual level of these faculty before they were hired. Analogously to the procedure used to obtain the results reported in figures 1-4, we examine trends in pre-hire output for faculty at the treated and non-treated departments by adding a dummy variable *Treat* to indicate whether the faculty member is hired at the treated departments and interaction terms of the year dummies and *Treated* to the equation:

$$\log Pub_{ict} = \beta_0 + \beta_1 Treated_{ict} + \sum \beta_t year_{ict} + \sum \gamma_t year_{ict} * Treated_{ict} + \varepsilon_{ict}; \quad (7)$$

where t=2001-2010, with the year 2000 as the base year. Coefficients of βt represent deviations of pre-hire output for faculty members hired by the C9 league between 2001 and 2010 from the level in 2000, while coefficients of γ_t reflect the comparable magnitudes for faculty hired at the *Treated* departments. In figures 7 and 8, the solid and dashed lines plot estimates of βt and r_t, respectively. Consistent with the earlier figures, weighted pre-hire publications and citations per faculty changed little in the pre-*TYTP* period. Importantly, the figures reveal that neither of those measures exhibit differential trends between faculty at the treated departments and faculty at the non-treated departments. Coefficients for the interaction terms are all small and statistically insignificant.[31]

Clearly, the figures demonstrate that both trends at the aggregate level and individual level are similar between the treated faculty members and non-treated faculty members before the implementation of *TYTP*. To account for other potential factors that might affect faculty

[31] Consistent with the aggregate data, coefficients of *Treated* are positive and large, indicating that faculty members at the treated departments might have higher pre-hire output.

research output, we also add control variables at the institution, publication year, and individual level in the regressions. *Inst* includes a set of institution fixed effects that capture differences in factors that might affect faculty research output across the C9 institutions that are constant over time. *Year* is a set of publication year fixed effects to account for changes in research output over time that are the same for all the C9 institutions. In addition, we add a rich set of individual level characteristics *X* including (i) gender, (ii) pre-hire postdoctoral training, (iii) year of hire, (iv) location of institution awarding the new faculty member's baccalaureate and PhD degrees, and (v) pre-hire publications. The full specification with further controls is below:

$$Publication_{ict} = \alpha + \beta_1 * TYTP_{ict} * Treat + \delta Year_t + \varphi Inst_c + \beta_2 x_{ict} + \varepsilon_{ict} \qquad (8).$$

Estimation Results and Further Discussion. Tables 8 and 9 report estimation results on number of weighted and weighted citations, respectively, with control variables that are added sequentially. Column 1 in both tables 8 and 9 reports estimates from the basic specification, with institution and publication year fixed effects included. Column 2 includes control variables for gender, postdoctoral experience, and year of hire; column 3 adds a dummy variable equal to one if the individual's PhD degree was obtained in a top-50 university abroad; column 4 adds a dummy variable indicating whether the individual's bachelor's degree was obtained in a C9-League university; and column 5 controls for publication- or citations before hire. The estimated coefficients of the interactive *TYTP*Treat* variable are remarkably consistent between tables 8 and 9 and robust across regression specifications, implying a roughly 15% decline in both the publication- and citation measures of faculty hired pre-*TYTP* after the introduction of *TYTP* hires. While we do not delve more deeply into possible causes of this rather surprising result, we

note that it is consistent with the negative competitive impact of Russian immigrants noted by Borjas and Doran (2012) cited above.

In order to gain some understanding of factors underlying the evidence of negative spillovers of *TYTP* on the publication/citation counts of faculty hired pre-*TYTP*, we gathered data of complete publication information for each hire in the sampled C9 institutions for years between 2011 and 2017. We then matched article titles among authors to obtain information on coauthorship. This procedure yields the information reported in table 10. The data in table 10 confirm that while *TYTP* hires have coauthored, they appear to have done so much less frequently than their non-*TYTP* counterparts in the treated departments. Moreover, those faculty hired by the non-treated departments, which by definition are all non-*TYTP* faculty, are substantially more likely to coauthor than their counterparts in the treated group (a mean of 2.6 coauthored papers per non-*TYTP* hire in the non-treated departments compared to 0.7 per non-*TYTP* hire in the treated group). One possible explanation for the higher frequency of coauthorship in the non-treated departments is that these departments are more likely to hire their own graduates, who would have established relationships with current faculty during their PhD training or before entering PhD programs elsewhere. Thus coauthorship would likely come relatively easily. In contrast, the treated departments are by definition more likely to hire *TYTP* scholars and thereby those who obtained a PhD from top institutions abroad between 2011 and 2017. It would appear to be much less likely that newly hired faculty from abroad had in the past collaborated with existing faculty members, leading to less likelihood of collaboration after hire.

VI. Conclusion

China activated its Thousand Young Talents Program (*TYTP*) as a component of its Thousand Talents Program in 2011. The program provides grants to supplement salaries and research support to enable Chinese academic and research institutions' hiring young Chinese nationals who have achieved outstanding records in top-level graduate and post-doctoral programs outside China. We examine indicators of *TYTP*'s achievements as measured by several metrics of academic background and research quality of new junior faculty hired by mathematics departments ranked among the top 20 in China.[32] These indicators include:

1. The ranking of PhD programs where new hires acquired their graduate training;
2. The pre-hire publication records of new junior faculty;
3. The pre-hire citation records of new junior faculty;
4. Evidence of the impact of *TYTP* junior faculty on the publications and citations of their colleagues who were hired before 2011.

We find very robust evidence of significant and substantial positive impact of *TYTP* on the proportions of new hires who received their PhD degrees from institutions ranked among the top-50 worldwide and located outside China. Event study results suggest that the proportion of hires with PhD degrees from top-50 departments abroad increased by approximately ten percentage points after the initiation of *TYTP* among China's top 20 math departments. Exploring the differential effects on hire quality between departments in the C9 institutions and the rest of the top 20 departments, we find that the increases are concentrated in departments in the elite C9 group. The estimates suggest that the C9 departments experienced a large and statistically significant increase in hire quality, with the proportion of new hires with PhD degrees from top 50 departments abroad increasing by more than 20 percentage points. By

[32] There are 24 departments in the top-20 due to tied scores. See Table 2.

contrast, the rest of the China's top 20 departments have seen little change in the hiring of scholars from highly ranked programs abroad. We examine publications and citations to articles published prior to hire date, inversely weighted by number of authors and adjusting citations for years since publication date, for C9 department junior hires. Weighted pre-hire publications rose by about one-fourth for the entire sample of hires in the departments in the C9 league, while citations to pre-hire publications (adjusted for citation lag) rose by nearly one half. The estimates are quite robust to alternative estimation strategies and specifications. The institution-, publication-, and citation-based measures of *TYTP* success provide robust evidence that the program has promoted significant increases in standard measures of faculty quality among China's elite mathematics departments. The improvements in faculty quality documented above may have additional beneficial impacts through migration decisions of international students and scholars. Kaushal, Neeraj, and Lanati (2019) show that between 2005 and 2015, China emerged as receiving the third-largest inflow of students from abroad enrolling in tertiary educational institutions. We infer that the potential return to studying in universities whose faculty are widely recognized internationally is a strong counterforce to the deterring effects of distance and language barriers as noted by Abbott and Stiles (2015) and Beine, Noël, and Ragot (2014).

The achievements may be sufficient to meet or surpass the goals set by policy makers. However, if those goals include contributing to the achievements of colleagues—spillovers that are a measure of increase in the pool of knowledge beyond that which would have occurred in absence of *TYTP* expenditures—then the program's success is perhaps less obvious. In order to examine spillover benefits of the program we compare the research productivity of faculty hired prior to the start of *TYTP* in the two C9 departments that hired no *TYTP* awardees prior to 2016 with that of comparable faculty in the other five C9 departments, controlling for a rich set of

individual level characteristics and institution and year fixed effects. We find statistically robust and quantitatively significant *negative* relationships between the treatment spillovers of *TYTP* on both weighted-publication and citation production of pre-*TYTP* hires. Both measures are about 15% lower among the faculty in the treated departments than among those in the non-treated departments. These impacts are supported by evidence of far less co-authorship of new hires with existing faculty in the treated departments than in the non-treated. We find the results striking and suggestive of further work on research productivity. For example, what are the factors that might affect collaboration, or lack of it, between *TYTP* hires and their colleagues? A possible policy implication following lack of evidence that *TYTP* hires create external benefits for their colleagues is to add criteria to the awarding of *TYTP* grants that give weight to prior relationships between the potential grantees and their future colleagues and provide incentives for collaboration between *TYTP* awardees and their colleagues. Thus, multiplier impacts of *TYTP* on the production of knowledge might emerge that would not be achieved otherwise.

High-skilled international migration has become more frequent in recent years, increasing the importance of investigating migration's relation to and impact on the research output of migrant scientists. Existing literature has found mixed evidence on the performance of migrant scholars relative to those who are less mobile. The significant increases in hire quality in top departments in China after the initiation of *TYTP* is consistent with the hypotheses that the program has induced the best and brightest scholars to return. However, a thorough investigation of this question would require detailed data on both returnees and their counterparts who did not return. A related question is whether migration enhances research productivity. Franzoni, Scellato, and Stephan (2014) suggest that migration itself could enhance performance. In our context, we would like to know whether research productivity of the *TYTP* hires has increased

relative to their counterparts who did not return. Further, we hope to explore whether the *TYTP* scholars are more productive than the homegrown researchers. As we have seen, the pre-hire publication measures for new hires in the two departments with fewer returnees after the initiation of *TYTP* actually experienced larger increases in published research than did those in the five departments who hired the bulk of new faculty with degrees from top institutions abroad. This comparison casts some doubt on whether the research performance of returnees has exceeded that of homegrown researchers in the 2011-2017 period. A deeper understanding of these aspects of migration and scientific output has important implications for developing effective policies to offset brain drain by attracting talented and productive researchers to strengthen the scientific workforce.

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Table 1 Graduate School Background of New Hires

Hire Years	2000-2010		2011-2017	
Proportions of New Hires with PhD Degrees from Institutions Ranked	Mean (1)	SD (2)	Mean (3)	SD (4)
Top 50[i] worldwide	0.230	0.421	0.318	0.466
Top 50 abroad only	0.0578	0.234	0.162	0.369
Top 50 domestic	0.172	0.378	0.156	0.364
Observations (Total Hires)	588		365	
C9 Departments[ii]				
Top 50 worldwide	0.319	0.467	0.442	0.498
Top 50 abroad only	0.0735	0.262	0.293	0.456
Top 50 domestic	0.245	0.431	0.150	0.358
Observations (Total Hires)	204		147	
Other Departments in Top 20				
Top 50 worldwide	0.182	0.387	0.234	0.424
Top 50 abroad only	0.0495	0.217	0.0734	0.261
Top 50 domestic	0.133	0.340	0.161	0.368
Observations (Total Hires)	384		218	

Notes: Sample includes non-foreign hires at the junior level in the 24 top 20 math departments in China (including tied rankings) over the years 2000-2017, based on CDR 2012. http://www.cdgdc.edu.cn/xwyyjsjyxx/xxsbdxz/2012en/index.shtml#.

[i]Top-50 graduate institutions based on QS World University Rankings by Subject – Mathematics https://www.topuniversities.com/university-rankings/world-university-rankings/2018.

[ii]C9 League as ranked in Project 985 https://en.wikipedia.org/wiki/Project_985.

Table 1a Quality Measures C9 Departments Restricted Sample

New Hires	2000-2010 Mean (1)	2000-2010 SD (2)	2011-2017 Mean (3)	2011-2017 SD (4)
Proportions with PhD degrees from Institutions Ranked as Indicated				
Prop. TYTP	0	0	.362	.483
Top 50	.347	.478	.443	.499
Top 50 abroad	.071	.258	.315	.466
Top 50 domestic	.277	.449	.137	.346
Numbers Before Hire[i,ii]				
Publications[i]	2.79	3.18	3.50	3.40
Citations[ii]	2.81	4.82	4.31	5.40
Hires	169		127	
C9 Departments with TYTP Junior Hires before 2016[iii]				
Proportion from top 50 abroad	.085	.279	.407	.494
Prop. TYTP	0	0	.484	.502
Publications[i]	3.12	3.34	3.84	3.84
Citations[ii]	3.02	4.82	4.14	5.55
Hires	130		91	
C9 Departments with No TYTP Junior Hires before 2016[iv]				
Proportion from top 50 abroad	.026	.160	.083	.280
Prop. TYTP	0	0	.056	.232
Publications[i]	1.67	2.25	2.64	1.64
Citations[ii]	2.10	5.08	4.75	5.02
Hires	39		36	

Notes: Sample includes non-foreign junior hires in the 7 top math departments in the C9 League from 2000-2017 for which we have sufficient data to evaluate publications and citations before hire. See text.

|Seven hires whose fields are identified as interdisciplinary are dropped.

[i]Publications are before hire and are per faculty author/divided by total number of coauthors. Publications are assigned to 2 years prior to year of publication. Thus, for someone hired in 2010, articles published through 2011 are assigned to the pre-hire period; for someone hired in 2017, articles published through 2018 are assigned to the pre-hire period.

[ii]The accumulated citations through year t are further divided by (1+(t-year published)). Citations are assigned to articles published according to note i. Thus, citations to articles published through 2012 are attributed to citations before hire for someone hired in 2011.

[iii.] Peking University, University of Science and Technology of China, Tsinghua University, Zhejiang University, and Shanghai Jiaotong University

[iv.] Harbin Institute of Technology and Xi'an Jiaotong University

Table 2 Institutions with Top 20 Departments in Mathematics

Institution	Score	Ranking	C9	Project 985	Region
Peking University	92	1	Y	Y	East
Fudan University	87	2	Y	Y	East
Shandong University	85	3		Y	East
University of Science and Technology of China	83	4	Y	Y	Central
Tsinghua University	81	5	Y	Y	East
Beijing Normal University	81	5		Y	East
Nankai University	81	5		Y	East
Wuhan University	80	8		Y	Central
Nanjing University	79	9	Y	Y	East
Zhejiang University	79	9	Y	Y	East
Sichuan University	79	9		Y	West
Xi'an Jiaotong University	79	9	Y	Y	West
Capital Normal University	77	13			East
Shanghai Jiaotong University	77	13	Y	Y	East
East China Normal University	77	13		Y	East
Jilin University	76	16		Y	Northeast
Xiangtan University	76	16			Central
Sun Yat-Sen University	76	16		Y	East
Lanzhou University	76	16		Y	West
Dalian University of Technology	74	20		Y	Northeast
Harbin Institute of Technology	74	20	Y	Y	Northeast
Soochow University	74	20			East
Xiamen University	74	20		Y	East
Central China Normal University	74	20		Y	Central

Notes: See Note to Table 1.

Table 3 Effect on Hire Quality

	PhD Top 50 Abroad 2000-2017							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TYTP	0.104***	0.106***	0.102***	0.111***	0.110***	0.106***	0.098***	0.116***
	(0.020)	(0.019)	(0.019)	(0.022)	(0.031)	(0.031)	(0.032)	(0.034)
Ranking			0.0004	0.0003	0.0003	0.0004	0.0004	0.0003
			(0.0020)	(0.0020)	(0.0021)	(0.0021)	(0.0021)	(0.0021)
College 985			0.119***	0.119***	0.119***	0.121***	0.122***	0.122***
			(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
College C9			0.070***	0.069***	0.069***	0.069***	0.069***	0.070***
			(0.022)	(0.022)	(0.023)	(0.023)	(0.023)	(0.023)
GDP growth				0.527	0.516	0.460	0.236	0.353
				(0.643)	(0.700)	(0.700)	(0.729)	(0.735)
Publication growth					-0.005	-0.038	-0.034	-0.055
					(0.119)	(0.120)	(0.120)	(0.121)
Students abroad						0.060*	0.057*	0.058*
						(0.032)	(0.033)	(0.033)
R&D funding							-0.021	-0.020
							(0.019)	(0.019)
Central		-0.015	0.062*	0.064*	0.064*	0.067**	0.069**	0.063
		(0.028)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.057)
West		-0.103***	-0.101***	-0.103***	-0.103***	-0.104***	-0.105***	-0.002
		(0.029)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.076)
Northeast		-0.103***	-0.102***	-0.103***	-0.103***	-0.103***	-0.103***	-0.027
		(0.025)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.058)
Region trend								Y
Constant	0.058***	0.091***	-0.053	-0.104	-0.102	-0.106	-0.078	-0.093
	(0.012)	(0.015)	(0.052)	(0.082)	(0.097)	(0.097)	(0.101)	(0.101)
Observations (Total Hires)	953	953	953	953	953	953	953	953
Adj R-squared	0.028	0.053	0.077	0.077	0.076	0.078	0.079	0.080

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: See Note to Tables 1 and 2. Sample includes non-foreign hires at the junior level in top 20 math departments from 2000-2017. Estimation results for equations (2)-(4): $Hire_{ict} = \alpha + \beta * TYTP_t + \gamma x_{ic} + \varepsilon_{ict}$. Ranking is the hiring institution's scalar ranking as shown in Table 2. Region dummies denote the location of the hiring university Central, Northeast, West (East region omitted). GDP growth is national growth averaged over three years prior to the hire year. Publication growth is the annual increase in the total number of publications in science and engineering produced in China. Student abroad growth is 5-year lag growth rate of the total number of students and scholars who go abroad. R&D funding is the increase rate in the annual investment in research and development at the national level. Pre-trend = 1 2000-2010; = 0 2011-2017.

Table 4 Effect on Hire Quality

	PhD Top 50 Abroad 2000-2017							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TYTP	0.024	0.023	0.024	0.032	0.022	0.015	0.009	0.015
	(0.024)	(0.024)	(0.024)	(0.027)	(0.035)	(0.035)	(0.036)	(0.039)
C9	0.024	0.012	-0.007	-0.008	-0.009	-0.012	-0.011	-0.009
	(0.025)	(0.025)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
TYTP_C9	0.195***	0.200***	0.203***	0.203***	0.204***	0.209***	0.208***	0.207***
	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)	(0.040)
Ranking			0.0012	0.0011	0.0011	0.0013	0.0012	0.0012
			(0.0020)	(0.0020)	(0.0020)	(0.0020)	(0.0020)	(0.0020)
College 985			0.127***	0.127***	0.127***	0.130***	0.131***	0.133***
			(0.0392)	(0.0392)	(0.0392)	(0.0391)	(0.0391)	(0.0393)
GDP growth				0.494	0.368	0.299	0.119	0.145
				(0.634)	(0.691)	(0.690)	(0.719)	(0.726)
Publication growth					-0.055	-0.094	-0.091	-0.100
					(0.118)	(0.119)	(0.119)	(0.120)
Students abroad						0.070**	0.068**	0.067**
						(0.032)	(0.032)	(0.032)
R&D funding							-0.017	-0.014
							(0.019)	(0.019)
Central		0.013	0.074**	0.076**	0.076**	0.079**	0.081**	0.039
		(0.027)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.056)
West		-0.085**	-0.100***	-0.102***	-0.103***	-0.104***	-0.104***	-0.031
		(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.076)
Northeast		-0.087***	-0.110***	-0.111***	-0.111***	-0.111***	-0.111***	-0.069
		(0.025)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.058)
Region trend								Y
Constant	0.050***	0.078***	-0.043	-0.091	-0.067	-0.071	-0.048	-0.055
	(0.015)	(0.017)	(0.052)	(0.081)	(0.096)	(0.096)	(0.099)	(0.100)
Observations (Total Hires)	953	953	953	953	953	953	953	953
Adj R-squared	0.077	0.094	0.102	0.102	0.101	0.105	0.105	0.105

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: See Notes to Tables 1, 2, and 3.

Table 5 Effect on Hire Quality C9 Institutions

	Log Weighted Number of Publications						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
TYTP	0.240***	0.252***	0.241***	0.276**	0.269**	0.277**	0.265*
	(0.082)	(0.081)	(0.093)	(0.124)	(0.124)	(0.127)	(0.160)
Ranking		-0.0058	-0.0055	-0.0055	-0.0047	-0.0045	-0.0045
		(0.0084)	(0.0085)	(0.0085)	(0.0085)	(0.0086)	(0.0086)
Region		0.219*	0.218*	0.217*	0.221*	0.221*	0.202
		(0.121)	(0.121)	(0.122)	(0.122)	(0.122)	(0.195)
GDP growth			-0.734	-0.327	-0.439	-0.147	-0.244
			(2.769)	(2.930)	(2.929)	(3.080)	(3.178)
Publication growth				0.225	0.117	0.0806	0.0818
				(0.525)	(0.531)	(0.545)	(0.546)
Students abroad growth					0.168	0.174	0.174
					(0.136)	(0.137)	(0.138)
R&D funding						0.027	0.030
						(0.086)	(0.089)
Region trend							Y
Constant	1.052***	0.934***	1.007***	0.924**	0.907**	0.870**	0.884**
	(0.0537)	(0.161)	(0.318)	(0.372)	(0.372)	(0.391)	(0.407)
Observations	296	296	296	296	296	296	296
Adj R-squared	0.025	0.048	0.045	0.042	0.044	0.041	0.038

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: See Notes to Table 4. Sample includes non-foreign hires at the junior level in the 7 top math departments in the C9 League from 2000-2017 for which we have sufficient data to evaluate publications and citations before hire. Estimation results for equations (5): $\log Pub_{ict} = \beta_0 + \sum \beta_t year_{ict} + \varepsilon_{ict}$.

Table 6 Effect on Hire Quality C9 Institutions

	Log Weighted Number of Citations						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
TYTP	0.420***	0.428***	0.456***	0.384**	0.378**	0.390**	0.448**
	(0.103)	(0.103)	(0.117)	(0.157)	(0.157)	(0.161)	(0.203)
Ranking		0.010	0.010	0.009	0.001	0.010	0.010
		(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Region		0.207	0.208	0.210	0.214	0.214	0.305
		(0.154)	(0.154)	(0.154)	(0.154)	(0.154)	(0.247)
GDP growth			1.710	0.882	0.779	1.171	1.630
			(3.509)	(3.711)	(3.714)	(3.906)	(4.029)
Publication growth				-0.459	-0.559	-0.607	-0.612
				(0.664)	(0.674)	(0.691)	(0.692)
Students abroad growth					0.154	0.163	0.164
					(0.172)	(0.174)	(0.174)
R&D funding						0.036	0.021
						(0.109)	(0.113)
Region trend							Y
Constant	0.866***	0.620***	0.451	0.620	0.604	0.555	0.488
	(0.0672)	(0.205)	(0.402)	(0.471)	(0.472)	(0.495)	(0.516)
Observations	296	296	296	296	296	296	296
Adj R-squared	0.051	0.050	0.048	0.046	0.045	0.042	0.040

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: See Notes to Table 5.

Table 7 Summary Statistics: Publications and Citations of Pre-TYTP C9 Junior Hires for Publication Years 2000-2017

Mean Yearly Publications and Citations	Full Sample[ii] Mean (1)	Full Sample[ii] SD (2)	Analysis Sample[iii] Mean (3)	Analysis Sample[iii] SD (4)
Weighted Publications per Individual [i]	0.775	0.915	0.787	0.978
Weighted Citations per Individual [i]	0.771	1.630	0.844	1.762
Observations[*]	2,616		1,612	
	Analysis Sample[iii]			
	2002-2011		2012-2017	
Weighted Publications per Individual [i]	0.769	0.938	0.803	1.013
Weighted Citations per Individual [i]	0.864	1.873	0.826	1.660
Observations[*]	755		857	
	Treated Departments[iv]			
Weighted Publications per Individual [i]	0.829	0.976	0.826	1.05
Weighted Citations per Individual [i]	0.975	2.02	0.863	1.71
Observations[*]	628		683	
	Non-Treated Departments[v]			
Weighted Publications per Individual [i]	0.472	0.652	0.713	0.855
Weighted Citations per Individual [i]	0.315	0.643	0.678	1.43
Observations[*]	127		174	

Notes: [*] Observations are total author-weighted publications over sample period.
Data are obtained from Scopus https://www.scopus.com/search/form.uri
i. Publications are per faculty author/divided by total number of coauthors. The accumulated citations through year t are further divided by (1+(t-year published)).
ii. Full Sample consists of observations on publications and citations by non-foreigners hired at the junior level between 2000 and 2010 in the 7 math departments in the C9 league for which we have data, summed over the years in the sample period. Total number of unweighted publications is 4131.
iii. Analysis Sample includes only those hired through 2009 for publication years between 2002 and 2017 in order to allow a two-year lag between hire and publication date. Total number of unweighted publications is 3126.
[iv] Peking University, University of Science and Technology of China, Tsinghua University, Zhejiang University, and Shanghai Jiaotong University
[v] Harbin Institute of Technology and Xi'an Jiaotong University

Table 8 Spillover Effects on Publications of Pre-TYTP C9 Junior Hires
Publication Years 2000-2017

	Log Weighted Number of Publications				
	(1)	(2)	(3)	(4)	(5)
TYTP*Treat	-0.151***	-0.127**	-0.128**	-0.154***	-0.134**
	(0.058)	(0.057)	(0.057)	(0.058)	(0.055)
Male		0.127***	0.127***	0.146***	0.104***
		(0.030)	(0.030)	(0.031)	(0.030)
Postdoc		0.089***	0.086***	0.065**	0.068***
		(0.026)	(0.026)	(0.027)	(0.026)
PhD Top 50 abroad			-0.013	0.058	0.001
			(0.035)	(0.036)	(0.035)
BA_C9				-0.068***	0.026
				(0.025)	(0.025)
Pre-Hire Publications					0.217***
					(0.017)
Publication Year FE	Y	Y	Y	Y	Y
Institution FE	Y	Y	Y	Y	Y
Hire Year FE		Y	Y	Y	Y
Constant	0.405***	0.247	0.250*	0.278*	0.031
	(0.150)	(0.152)	(0.152)	(0.155)	(0.148)
Observations	1,612	1,597	1,597	1,395	1,395
Adj R-squared	0.026	0.043	0.042	0.083	0.185

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: See notes to Table 7. Sample includes publications of junior hires between 2000 and 2009 in the 7 top math departments in the C9 League. Individual characteristics include gender, pre-hire postdoctoral training, whether went to a C9 institution for undergraduate degree, whether obtained PhD degree from an overseas institution abroad, and number of weighted publications before hire.

Table 9 Spillover Effects on Citations of Pre-TYTP C9 Junior Hires
Publication Years 2000-2017

	Log Weighted Number of Citations				
	(1)	(2)	(3)	(4)	(5)
TYTP*Treat	-0.179**	-0.156**	-0.157**	-0.178**	-0.150**
	(0.070)	(0.070)	(0.070)	(0.073)	(0.065)
Male		0.109***	0.113***	0.154***	0.144***
		(0.037)	(0.037)	(0.039)	(0.035)
Postdoc		0.090***	0.071**	0.042	0.071**
		(0.032)	(0.032)	(0.034)	(0.030)
PhD Top 50 abroad			-0.109**	-0.077*	-0.117***
			(0.043)	(0.046)	(0.041)
BA_C9				-0.030	0.012
				(0.031)	(0.028)
Pre-Hire Citations					0.313***
					(0.016)
Publication Year FE	Y	Y	Y	Y	Y
Institution FE	Y	Y	Y	Y	Y
Hire Year FE		Y	Y	Y	Y
Constant	0.302*	0.159	0.187	0.183	0.029
	(0.183)	(0.186)	(0.186)	(0.195)	(0.173)
Observations	1,612	1,597	1,597	1,395	1,395
Adj R-squared	0.043	0.051	0.054	0.079	0.277

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

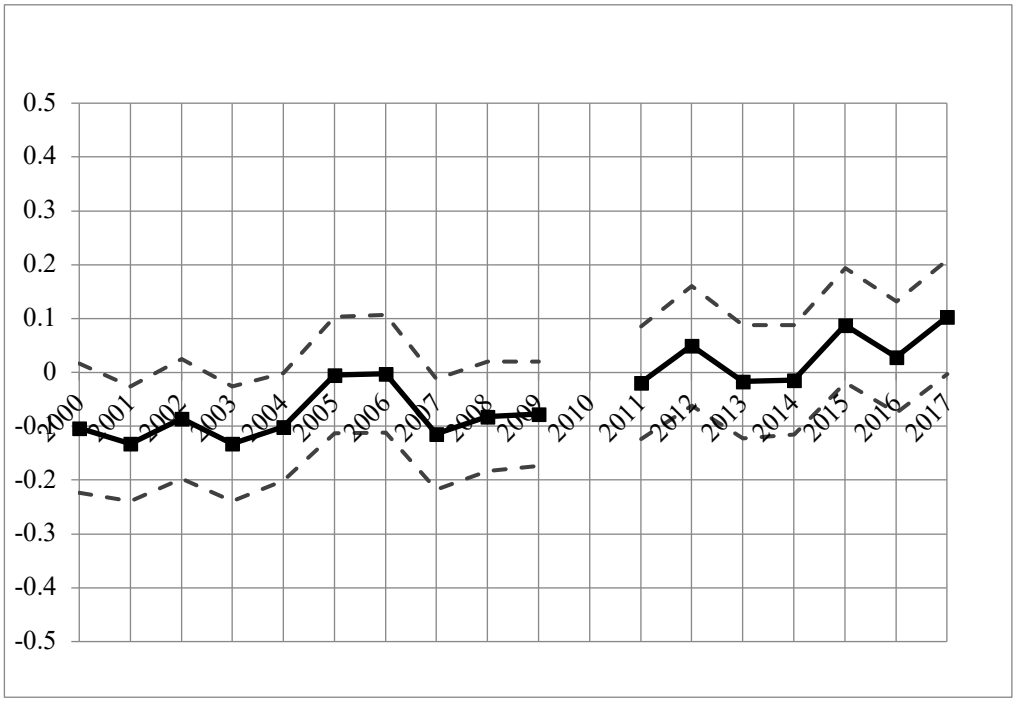
Notes: See notes to Tables 7 and 8.

Table 10 Coauthored Publications among Faculty Hired between 2011-2017

	Coauthored Publications			
	TYTP Hires		Non-TYTP Hires	
	Number	Per hire	Number	Per hire
	(1)	(2)	(3)	(4)
Treated Departments	7	0.156	42	0.7
Non-treated Departments	0	0	113	2.628
Peking University	2	0.111	1	0.125
Tsinghua University	0	0	4	0.308
University of Science and Technology of China	0	0	16	1.6
Zhejiang University	3	0.3	4	0.286
Shanghai Jiaotong University	2	0.333	17	1.133
Harbin Institute of Technology	0	0	31	1.632
Xi'an Jiaotong University	0	0	82	3.417

Notes: The table reports measures of coauthored papers among faculty hired between 2011-2017 at the treated and non-treated departments, respectively. Coauthored papers could be published before or after hire with any colleague hired between 2000 and 2017.

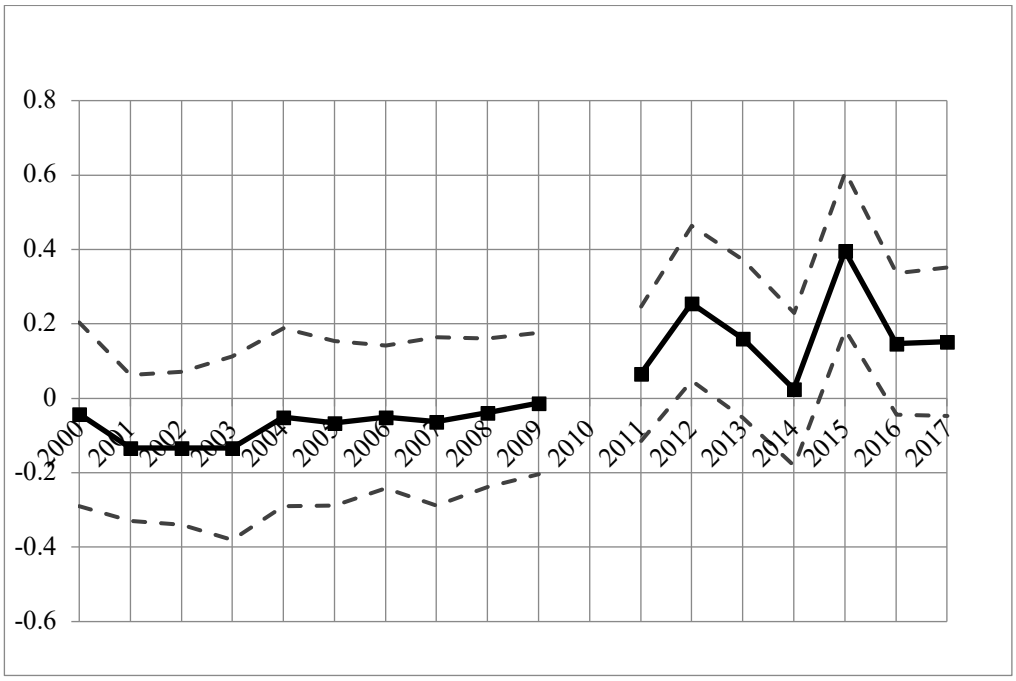
Figure 1 Proportion of Hires with a Degree from Top 50 Departments Abroad



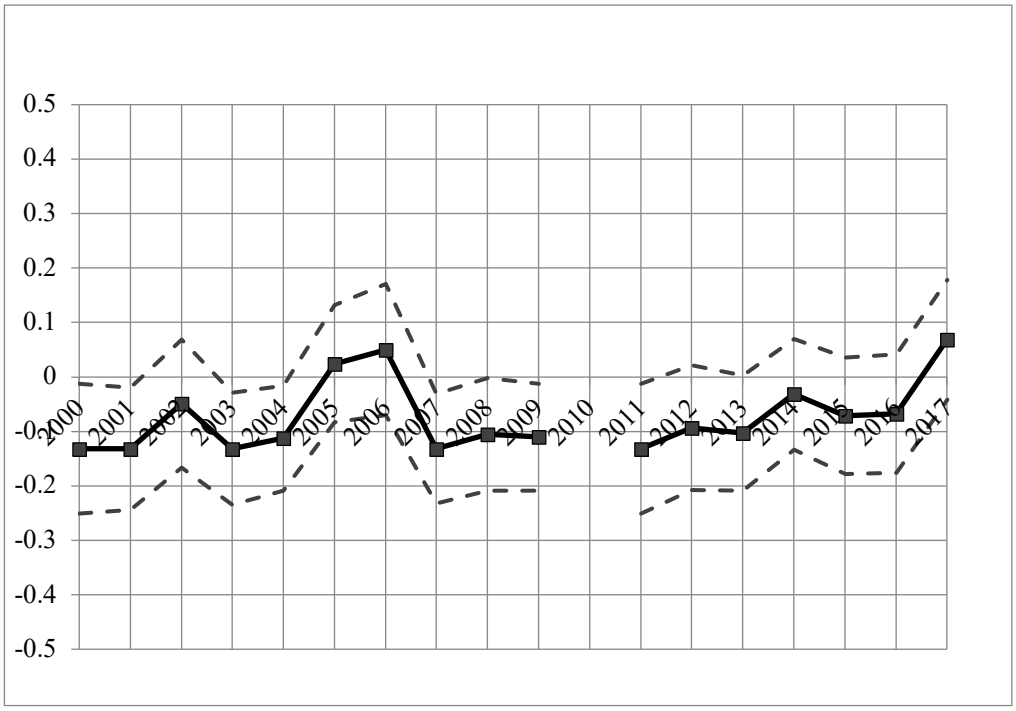
Notes: See notes to Table 1 and 1a. Figure plots estimates of β_t from equation (1) $Hire_{ict} = \beta_0 + \sum \beta_t year_{ict} + \varepsilon_{ict}$, t=2000-2009; 2011-2017, along with their 95% confidence interval. The coefficients reflect deviations from the measure of hire quality in 2010, the year before the implementation of TYTP.

Figure 2 Proportion of Hires with a Degree from Top 50 Departments Abroad (Restricted Sample)

Panel A C9 Institutions

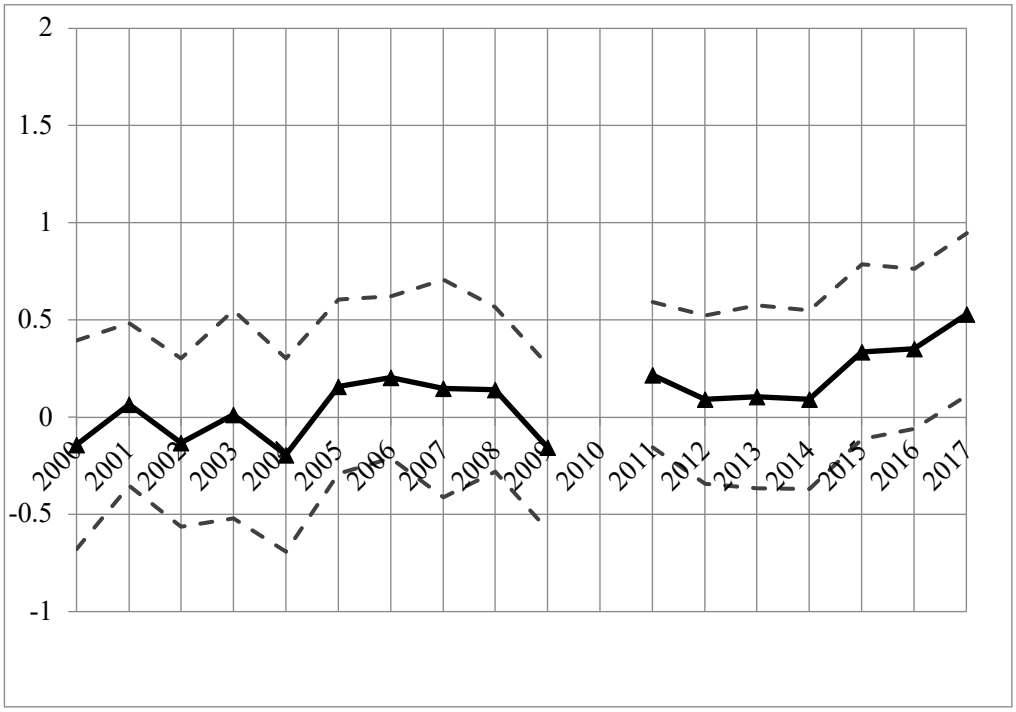


Panel B Non C9 Institutions



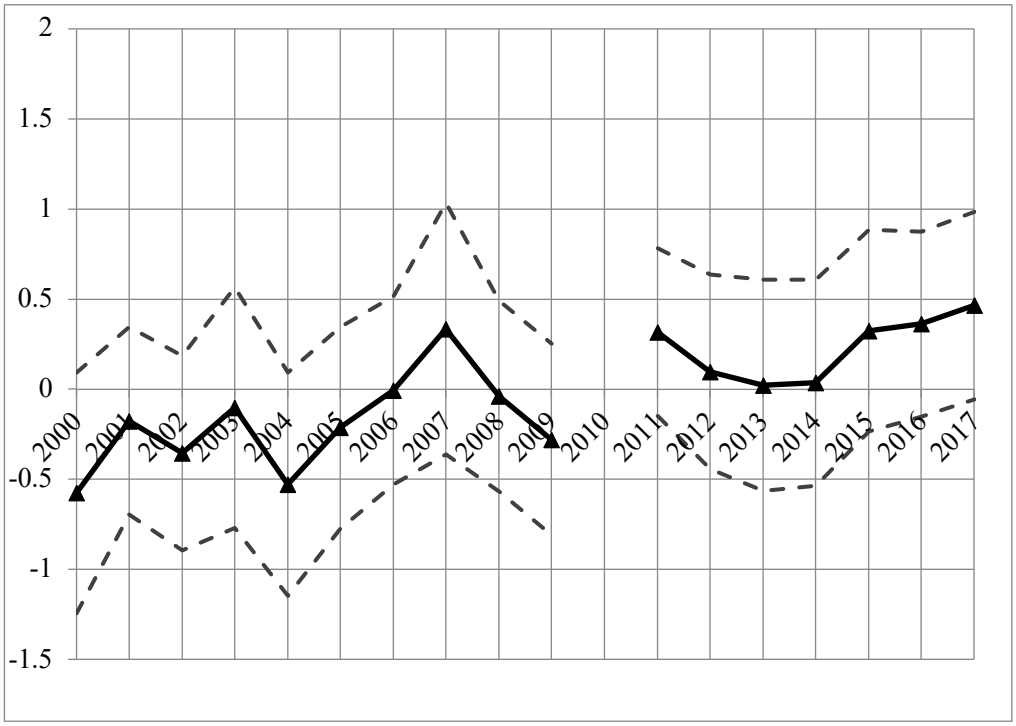
Notes: See Notes to Figure 1. C9 sample is restricted to the 7 institutions for which we have information on hire year, educational background, publication data, and related measures for at least 40 percent of faculty members.

Figure 3 Log Weighted Number of Publications C9 Institutions



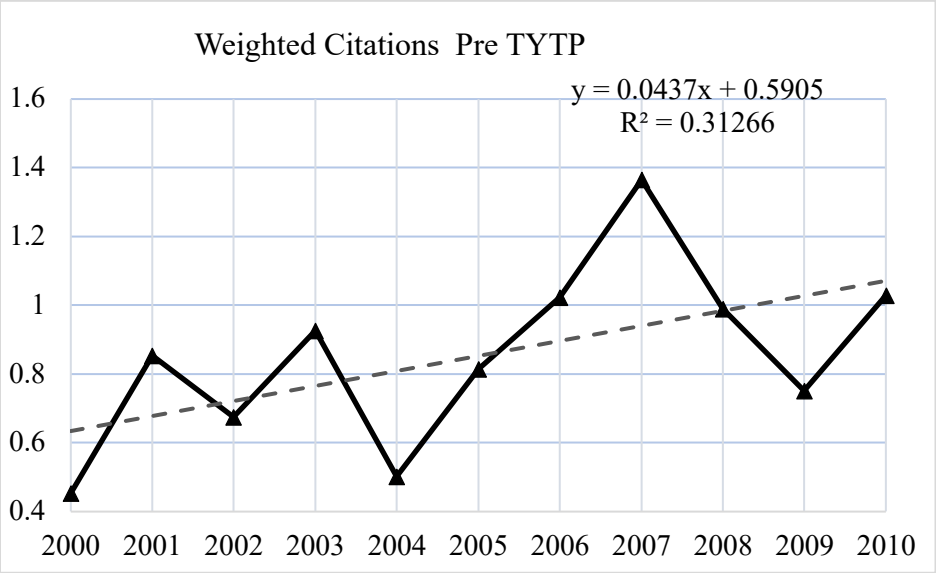
Notes: See notes to Figures 1 and 2. Figure is based on estimates from equation (5) $\log Pub_{ict} = \beta_0 + \sum \beta_t year_{ict} + \varepsilon_{ict}$; t=2000-2009; 2011-2017, along with the 95% confidence intervals. The coefficients reflect deviations from the level of hire quality in 2010, the year before the implementation of TYTP.

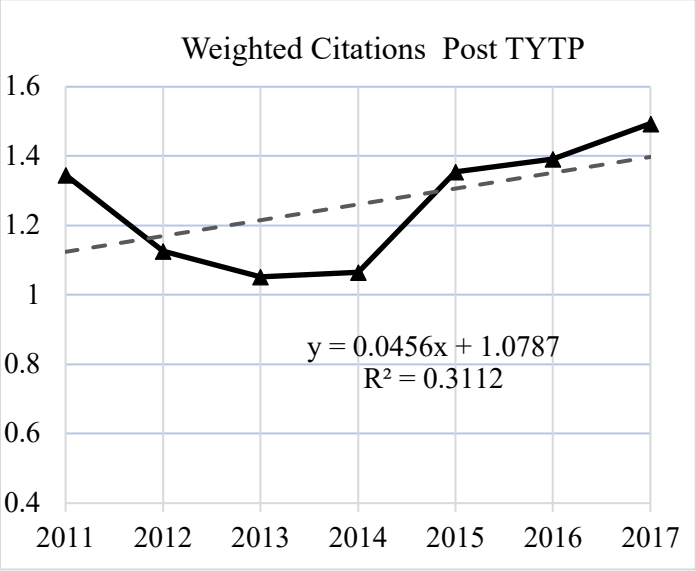
Figure 4 Log Weighted Number of Citations C9 Institutions



Notes: See notes to Figure 3.

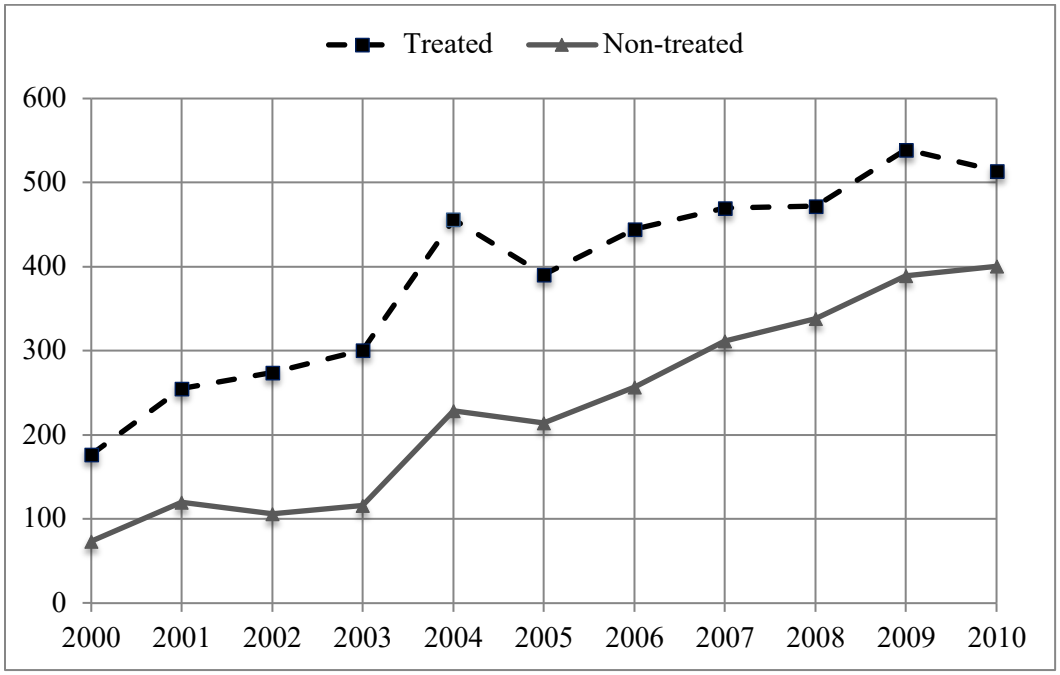
Figure 5 Log Weighted Number of Citations C9 Institutions





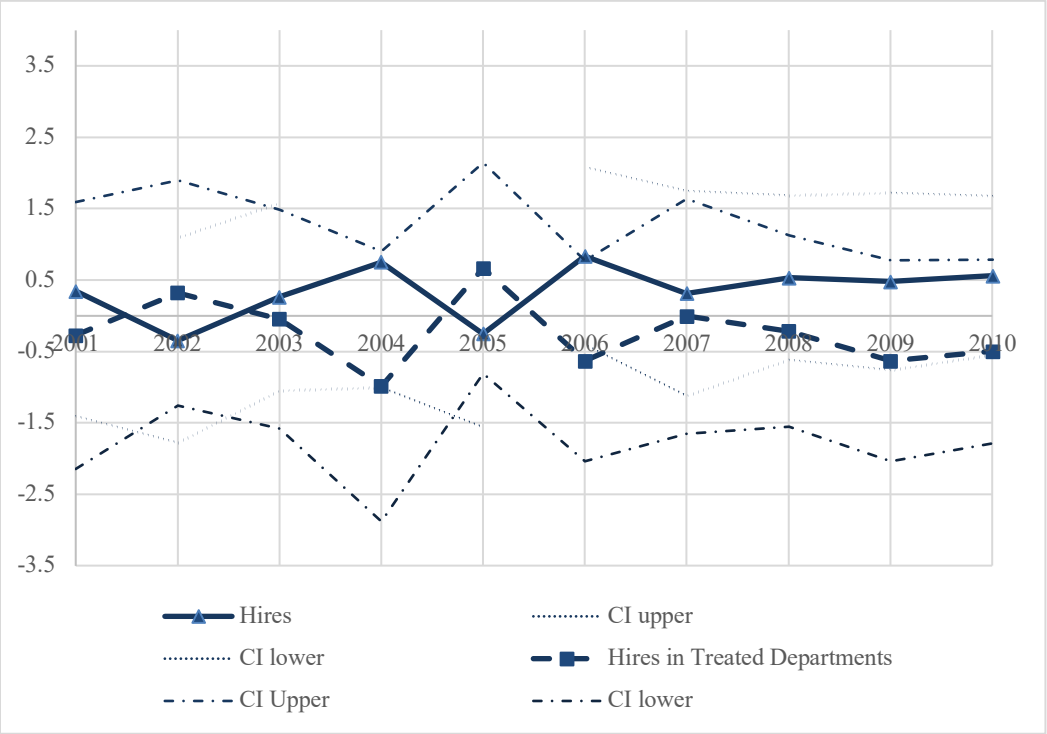
Notes: See notes to Figures 3. Figure plots estimates of from equation (5) without constant term but including dummy variable for each year, $\log Pub_{ict} = \sum \beta_t year_{ict} + \varepsilon_{ict}$; t=2000-2009; 2011-2017.

Figure 6 Publications by Mathematics Faculty C9 Institutions



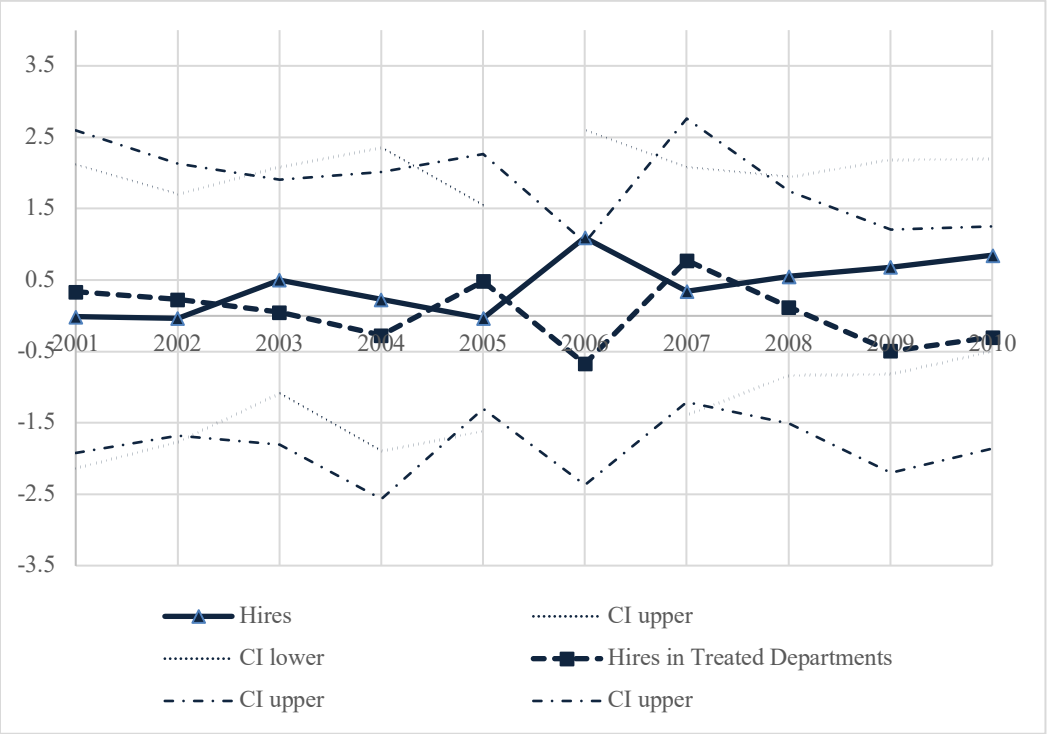
Notes: Data from Scopus. https://www.scopus.com/search/form.uri
See notes to Table 7.
i.The lines plot the average number of publications per year by faculty members in mathematics at the treated and non-treated departments.
ii. Treated departments are those in the five C9 institutions that hired some TYTP scholars; non-treated are the remaining two departments (of the 7 C9 institutions for which we have data) that hired no TYTP scholars relevant to our sample period.

Figure 7 Log Weighted Number of Pre-Hire Publications, C9 Junior Hires



Notes: Sample includes pre-hire publication records for junior faculty at the C9 departments hired between 2000 and 2010. Figure is based on estimates from $\log Pub_{ict} = \beta_0 + \beta_1 Treated_{ict} + \sum \beta_t year_{ict} + \sum \gamma_t year_{ict} * Treated_{ict} + \varepsilon_{ict}$; t=2001-2010, along with the 95% confidence intervals. Year 2000 is the base level. The coefficients reflect deviations in log pre-hire publications from the level of hire quality in 2000. Coefficient for the constant term is 0.3466, coefficient for *Treat* is 0.7019.

Figure 8 Log Weighted Number of Pre-Hire Citations, C9 Junior Hires



Notes: Sample includes pre-hire citation records for junior faculty at the C9 departments hired between 2000 and 2010. Figure is based on estimates from equation $\log Pub_{ict} = \beta_0 + \beta_1 Treated_{ict} + \sum \beta_t year_{ict} + \sum \gamma_t year_{ict} * Treated_{ict} + \varepsilon_{ict}$; t=2001-2010, along with the 95% confidence intervals. Year 2000 is the base level. The coefficients reflect deviations in log pre-hire citations from the level of hire quality in 2000. Coefficient for the constant term is 0.0357, coefficient for *Treat* is 0.5368.