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ABSTRACT

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

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 the top Chinese mathematics departments' new hires, we find that the program leads to considerable increases in measures of their educational background and research productivity. The effects are concentrated in the elite C9 league, where the proportion of hires who received PhD degrees from top-50 overseas mathematics departments increased nearly four times after the initiation of the program. The data also reveal large and statistically significant increases in weighted pre-hire publications and weighted citations to pre-hire publications under the program. However, it appears that research output of previously hired faculty members declined after the introduction of TYTP hires, suggesting minimal or even negative impact of TYTP on faculty colleagues' academic achievements.

JEL Classification: J61, O31, O38

Keywords: migration, scientific research, R&D policy

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I. Introduction.

We report the impact of China's Thousand Young Talents Program (*TYTP*) on the return of young overseas scholars to highly ranked academic positions in China, their home country. China's 2011 expansion of its 1000 Talents Program to new PhDs marked a major increase in its scope and funding.[1]The program aims to attract overseas scholars under age 40 in science and engineering with generous support to work full time in China. Because of the complexity and availability of required data obtained from department records and individuals' curricula vitae (CV) our focus here is narrowed to mathematics scholars.[2]

We find that *TYTP* has achieved considerable success as measured by (i) the increase in the number of jobs filled by young scholars with PhD degrees earned from top-ranked overseas institutions; (ii) the growth in the number of publications of these new hires prior to their return; and (iii) the quality of these publications as measured by citations by other scholars in their published work. Event-study results conservatively indicate a doubling in the proportion of new hires with PhDs from top-50 mathematics departments outside China and a similarly large increase in the quality of pre-hire publication achievements for new hires.

Although *TYTP* grants are not constrained to a particular set of institutions, they are predominately awarded only to top-level institutions.[3] Our results indicate that newly hired *TYTP* mathematicians are indeed concentrated in departments in the top tier of highly-ranked institutions—those in the Project 985 C9 League.[4] 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. Associated with these impacts, we find evidence that top-20 institutions in China have been marginally less likely to hire new faculty from worldwide top-50 mathematics departments located in China after opening of the *TYTP* program in 2011.

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[1] 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,

[2] There are a number of discipline-specific studies of aspects of international migration of scholars in other areas. See Hunter, Oswald, and Charlton (2009), McDowell and Singell (2000), Albarran, Carrasco, and Ruiz-Castillo (2017) etc.

[3] https://en.wikipedia.org/wiki/Thousand_Talents_Program#Selection

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

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. Exploiting the regional variation in the distribution of *TYTP* awards, we find that the introduction of *TYTP* hires is associated negatively with the research output of their colleagues who were hired before *TYTP*. We 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 literature surrounding researchers' and policy makers' interests in understanding the determinants of scientists' mobility and its impact on innovation and economic growth. This topic has received broad attention in the literature on the "brain drain" at least since 1965 as documented by Bhagwati (2010) in his Preface to the Symposium on the Brain Drain published in the *Journal of Development Economics*. To cite just two of the Symposium's paper, Weinberg (2010) documents the need for developing countries to achieve and maintain a strong scientific community; Dustmann, Fadlon, and Weiss (2010) develop a model explaining decisions to acquire human capital in locations where it is more efficient to do so and decisions that underly return migration. In more recent literature, for example, 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. Thus, we should anticipate a positive response to the incentives created through *TYTP* grants, encouraging new Chinese PhDs abroad to return to China.

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, which we take as consistent with the importance of the financial incentives associated with *TYTP* grants. Gaulé also finds that new PhDs and young faculty are the most likely to take advantage of opportunities to return to their home countries.

Grogger and Hanson (2015) report that in many years, 90 percent or more of Chinese and Indian graduate students earning Science and Engineering PhDs in the United States have intended to remain in the United States. While this is a higher proportion than among graduate students from the Republic of Korea or Taiwan, planned return rates among Korean and Taiwan

students have grown considerably in the twenty-first century, and the authors demonstrate a positive association with political reform and democratization in these two countries. 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.

Franzoni, Scellato, and Stephan (2014) draw evidence from lifetime mobility to infer that migration itself may help select potentially more productive researchers from those who are less mobile. They also find that the superior performance of migrant scientists persists after using instrumental variables to address the selection issue. Gaulé and Piancentini (2013) report that admission of Chinese applicants to United States chemistry graduate programs is highly selective and that an important criterion is the level of university in China from which the applicant has graduated. Thus, Chinese graduate students in the United States have already passed the extraordinary criteria required to enroll in the very top Chinese universities. This stringent screening, along with the anecdotal evidence that Chinese students are relatively hard working, helps to explain why quality-adjusted publications of Chinese PhD students in United States chemistry departments is on a par with domestic graduate students who have been awarded NSF doctoral fellowships.

Using an extremely constrained data base of 158 most highly cited physicists moving between the United Kingdom and the United States, Hunter, Oswald, and Charlton (2009) find little to distinguish between the productivity of movers and stayers. McDowell and Singell (2000) find that immigrant economists in the United States are at least as productive as natives, and cohorts entering the U.S. after 1975 appear to be more productive than natives. Using more recent data, Albarran, Carrasco, and Ruiz-Castillo (2017) perform a similar study and find that among elite economists there is little to distinguish the productivity and/or impacts of movers and stayers.

In contrast, however, Hunt and Gauthier-Loiselle (2010) employ an aggregative approach using 1940-2000 state data on immigration of college graduates and find evidence of positive spillovers from scientifically trained immigrants to domestic innovation, identifying a positive relationship between the share of skilled immigrants and per-capita patents. The authors also use

[5] Their Figure 5.Their analysis uses data from Survey of Earned Doctorates through 2008.

individual level data and find that the patenting rate among immigrants is double that of natives, primarily due to their concentration in Science and Engineering fields.

Borjas and Doran (2015), using a nicely constrained sample that nevertheless covers a broad distribution of movers and stayers, study the emigration of mathematicians following the 1992 political revolution in the Soviet Union to identify the impact of reduced competition among those who remained and whose work competed in idea space and/or worked in the same departments as the emigrants. They also examine how the emigration of a collaborator affected the work of those who did not leave the Soviet Union. They report evidence that a smaller number of scholars publishing in the same area of mathematics is associated with increased publication by non-émigrés of approximately 7 percent; consistent with this impact of within-area competition, Borjas and Doran (2012) find that the influx of Soviet mathematicians negatively impacted the research output of American mathematicians in overlapping areas. In contrast, the loss of prominent collaborators had significantly negative impacts on the publications of those who remained in the Soviet Union. Overall, geographic proximity (being employed in the same department) alone appears to have had little impact on the publication productivity of stayers.

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. 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

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

Scopus[7], we also construct a sample of complete publication profiles for new hires from the mathematics departments in the Project 985 C9 subset[8] of these departments during the sample period. *TYTP* awardees account for 74, approximately 20.2% of the 365 faculty hired after 2010 included in our sample after the sample is trimmed of observations with insufficient data for our estimation exercises.

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. Our total sample before some trimming as required for careful estimation consists of 953 new mathematics-department faculty hires over the 2000-2017 period. 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.

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.

[7] https://www.scopus.com/search/form.uri?display=basic
[8] https://en.wikipedia.org/wiki/Project_985.

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.[9]

We obtain information on publications and citations as perhaps more compelling evidence of professional quality than the education background of new hires. However, 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. These departments are listed in the notes to Table 1a, which reports summary statistics for this restricted sample.

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)). Thus, for someone hired in year 2012, articles published in years leading up to and including 2010 are counted as pre-hire publications. Citations counted in 2018 to a solely authored article published in the year 2010 would be divided by (1+(2018-2010) = 9).

For the 7 C9 departments in our restricted sample, the mean weighted number of publications before hire for all new hires increased by approximately 1.25 times in the period 2011-2017, and the mean weighted citations by 1.5 times. We note that standard deviations are

[9] See Table 1 notes for reference to the C9 League of universities.

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. Nevertheless, we believe that further analysis is warranted and do so in our empirical investigations.

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,

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

The outcome variable is a measure of hire quality as defined for equation (1)[10], *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.[11]

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 [12], 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[13].

[10] We have also 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.
[11] The universities in the sample are national universities and receive funding from the Ministry of Education of the People's Republic of China.
[12] Grogger and Hanson (2015).
[13] Data calculated based on the World Development Indicators by the World Bank (http://datatopics.worldbank.org/world-development-indicators/).

2. A measure of the growth in total number of publications in science and engineering produced in China using data obtained from Scopus[14] 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[15].
4. Annual R&D funding data is added to capture time varying characteristics in hiring institutions' research environment.[16]
5. As a further robustness check, we add a region-specific linear trend, *T*, to control for any underlying trend at the local level.[17]

The fully modified specification is

$$Hire_{ict} = \alpha + \beta^{*} TYTP_{t} + \gamma x_{ic} + \phi z_{t} + \delta T_{rt} + \varepsilon_{ict} \qquad (3)$$

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.

[14] 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.

[15] 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.

[16] Data collected from China Statistical Yearbook, annual series published by Ministry of Education of the People's Republic of China.

[17] 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.

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.

Distribution Between C9 Institutions and Other Top-20 Institutions.

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

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

where the variable *C9* = 1 for institutions included in the *C9* league, = 0 for the remaining top-20 institutions [18].

IV. Estimation Results:

We report results for equation (1) both graphically and in tabular form. .

i. *New Hires with PhD Degree from Top-50 Abroad Mathematics Departments.*

a. Quality of PhD-Granting Institution: Graphical Presentation.

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

[18] 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.

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 mean number of non-foreign hires in all top-20 mathematics departments who received their PhD degrees from overseas departments among the worldwide top-50 increased from 0.07 over 2000-2010 to 0.17 from 2011 through 2017. The comparable figures for hires from all worldwide top-50 programs rose from 0.23 prior to *TYTP* to 0.32 after its initiation in 2011.

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 confirmed in 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.

b. *Expanded Model: Regression Analysis.*

In equations (2) - (4) we specify estimation models that 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.[19]

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

[19] Probit estimation suggests a marginal effect of 8.93 percent increase at the mean.

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.[20] 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 have new hires from top-50 departments abroad compared to those in the East 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 side factors on hire quality.

ii. 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.[21]

a. *Data and Sample.*

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. We obtain a list of current faculty members from department websites and date of hire from each faculty member's CV, personal web page, and other sources on the internet. Our final sample consists of 296

[20] 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.
[21] Galiani and Gálvez (2017) examine the life-cycle pattern of citations.

mathematics-department faculty in the seven universities for which we have information on hire year for over 40 percent of all faculty members. The universities are Peking University, University of Science and Technology of China, Tsinghua University, Zhejiang University, Xian Jiaotong University, Shanghai Jiaotong University, and Harbin Institute of Technology.[22]

To construct publication profiles, we search Scopus[23] for each member of our sample by name, affiliation, and discipline. In most searches, the three criteria allow us to uniquely identify each individual in our sample. We then collect each researcher'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 for hire quality for each faculty member: (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.

Summary statistics are reported in table 1a. There are striking changes in output measures of the quality of hires. Following the initiation of *TYTP* in 2011, the weighted publication-based indices of newly hired junior faculty quality increased from 2.79 to 3.50 and weighted citations from 2.81 to 4.31 after the initiation of *TYTP*.

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

b. Results.

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.

[22] In two C9 universities, Fudan University and Nanjing University, the majority of faculty members do not have a personal webpage and there is limited information on the website.
[23] https://www.scopus.com/search/form.uri

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)-(8) 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, (vi) region linear trend, and (vii), a pre-event trend variable = 1-11 in the years 2000-2010 and 0 thereafter 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 those reported in column (1). Similar to the regression with dependent variable representing PhD from a top-50 overseas institution, when the pre-trend variable replaces the region*trend variable (column 8) the magnitude of the *After* regression coefficient roughly doubles in magnitude from 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 and 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 discouraged innovation among those working on similar topics in migrants' destinations. The possibility of negative spillovers to the productivity of 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.

i. *Data and Sample.*

The total sample of pre-*TYTP* hires includes 172 junior faculty who joined the mathematics departments in the C9 league between 2000 and 2010. 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 these faculty members, we collect complete

publication data from the date of their first article through the year 2017 from Scopus[24]. 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. 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 [25].

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 some specifications, we use publications before hire to account for heterogeneity in hire quality.) 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) in order to clearly mark the point at which the impact of *TYTP* hires on their colleagues' research can be evaluated, given our assumption of a two-year publication lag. [26]

The Analysis Sample consists of a panel with 1612 author-weighted publications summed over individual researchers and publication years.[27] 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. As indicated in Table 7, we

[24] Data were available for years 2018 and 2019, but we thus did not include publications in these two years as they might be incomplete.
[25] We focus on publications in professional journals and do not include conference proceedings. The total number of (unweighted) publications is 4131.
[26] Results are robust to including the 2010 hires.
[27] The total number of publications is 3126.

designate the two mathematics departments that hired no *TYTP* junior faculty before the year 2016 as "Non-Treated" by *TYTP* and the remaining five as "Treated" by *TYTP*. [28]

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 Non-Treated institutions is due to applicant preferences for favored location in the central and coastal provinces, where the five Treated institutions are located. As seen in in table 1a, the five Treated 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.

A further surprise in Table 7, notwithstanding that there are only two Non-Treated C9 mathematics departments, is that while weighted publications per individual faculty member were barely half and weighted citations less than one-third those of faculty in the Treated group, they reached approximately 80% of the weighted publications and citations after the introduction of *TYTP*. Moreover, neither quality measure for faculty in the Treated group is higher in the presence of *TYTP* than in the preceding period.

Similar trends appear in the series for total publications as illustrated in Figure 6, which plots the departmental average number of academic publications in mathematics produced by faculty in the Treated departments and the Non-Treated departments. While the departmental output of the five departments is higher than the remaining two departments, the trends are similar between 2000 and 2010.

A somewhat more formal summary of the publications- and citations data is reported in Figures 7 and 8, respectively, based on plots of β_t obtained by estimating

$$y_{ict} = \beta_0 + \sum \beta_t * Pubyear_{ict} + \delta Hireyear_{ict} + \varepsilon_{ict}, \text{ t =2002-2011; 2013-2017,} \quad (6)$$

[28] The five departments in the East and Central regions collectively received 44 *TYTP* scholars, approximately 95.7% of awardees. 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, but this observation was dropped due to the interdisciplinary fields. The two *TYTP* hires are likely to be too recent to affect output of the existing hires.

[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.

analogously to the procedure used to obtain the results reported in Figures 1-4. The sample includes publications of junior faculty who were hired between 2000 and 2009 in the 7 top math departments in the C9 League. The dashed and solid lines plot β_t obtained from separate estimates for the Treated and Non-Treated departments, respectively, and they represent deviations of weighted publications/citations per faculty hired between 2000 and 2009 from their levels in 2012. The graphs suggest that the Non-Treated departments were converging with the Treated departments in terms of publications prior to 2012 and in citations as well, although there are less obvious patterns in the trends of weighted citations.[30] Moreover the lines suggest both measures are higher in the post-*TYTP* period than in the years up to and including 2011 in the Non-Treated departments, whereas there seems to be little difference in the average level of either the publication- or citation measures among the Treated departments. These plots, along with the data cited above would appear to be grossly inconsistent with the existence of beneficial spillovers from *TYTP* hires to their colleagues.

ii. <u>*Estimation Strategy*: *Treated and Non-Treated Departments*</u>.

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 conduct a difference-in-difference test for the benefits of having *TYTP* colleagues, specifying the equation

$$Publication_{ict} = \alpha + \beta_1 * TYTP_{ict} * Treat + \delta Year_t + \varphi Inst_c + \varepsilon_{ict} \qquad (7),$$

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 1 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 1 if the researcher is hired by one of the five institutions that experienced a large increase in *TYTP* scholars after the program began and equals zero for the remaining two C9s. *Inst* includes a set

[30] We note that there is a small number of observations in the early years. Specifically, only hires in 2010 contribute to the 2002 publication measures.

of institution fixed effects that account for 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.

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. In addition to the institution and publication year fixed effects, 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,

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

iii. *Estimation Results.*

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 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 on 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.[31] 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;

[31] https://en.wikipedia.org/wiki/Thousand_Talents_Program
[32] There are 24 departments in the top-20 due to tied scores. See Table 2.

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 hired before 2011.

Controlling for pre-*TYTP* trends and institutional- and regional fixed effects we find very robust evidence of significant and substantial increase in the proportions of new hires who received their PhD degrees from institutions ranked among the top-50 worldwide and located outside China. This measure of success is much more pronounced for departments situated in China's C9 universities (nearly 4-fold increase) than in other departments among the top-20 (nearly 50% increase and quite robust to alternative estimation strategies and specifications.

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 departments in the C9 institutions experience 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 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 more than one-third. The institution-, publication-, and citation-based measures of *TYTP* success provide robust evidence that the program has promoted significant increases to standard measures of faculty quality among China's elite mathematics departments. These improvements in faculty quality might further affect 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 & Stiles (2015) and Beine, Noël, and Ragot (2014).

These 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 (non-treated departments) with that of comparable faculty in the other five (treated) C9 departments. Although the sample of non-treated departments is admittedly small, we nevertheless find the results striking and suggestive of further research on research productivity. 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 were 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.

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.

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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	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		2011-2017	
	Mean	SD	Mean	SD
	(1)	(2)	(3)	(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.

ıSeven 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
Xian 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***	0.0975***	0.116***
	(0.0195)	(0.0193)	(0.0191)	(0.0223)	(0.0308)	(0.0308)	(0.0317)	(0.0344)
Ranking			0.0004	0.0003	0.0003	0.0004	0.0004	0.0003
			(0.0020)	(0.002)	(0.0021)	(0.0021)	(0.0021)	(0.0021)
College 985			0.119***	0.119***	0.119***	0.121***	0.122***	0.122***
			(0.0397)	(0.0397)	(0.0397)	(0.0397)	(0.0397)	(0.0398)
College C9			0.0701***	0.0689***	0.0688***	0.0679***	0.0691***	0.0700***
			(0.0224)	(0.0224)	(0.0225)	(0.0225)	(0.0225)	(0.0225)
GDP growth				0.527	0.516	0.460	0.236	0.353
				(0.643)	(0.700)	(0.700)	(0.729)	(0.735)
Publication growth					-0.00510	-0.0383	-0.0340	-0.0546
					(0.119)	(0.120)	(0.120)	(0.121)
Students abroad						0.0602*	0.0574*	0.0576*
						(0.0324)	(0.0325)	(0.0325)
R&D funding							-0.0210	-0.0197
							(0.0191)	(0.0193)
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-values shown below standard errors. *** 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	0.0239	0.0234	0.0235	0.0324	0.0222	0.0149	0.0088	0.0150
	(0.0242)	(0.0241)	(0.0241)	(0.0267)	(0.0347)	(0.0348)	(0.0355)	(0.0391)
C9	0.0241	0.0118	-0.00693	-0.00793	-0.00916	-0.0121	-0.0106	-0.00912
	(0.0247)	(0.0247)	(0.0266)	(0.0266)	(0.0267)	(0.0267)	(0.0268)	(0.0269)
TYTP_C9	0.195***	0.200***	0.203***	0.203***	0.204***	0.209***	0.208***	0.207***
	(0.0392)	(0.0390)	(0.0389)	(0.0389)	(0.0391)	(0.0390)	(0.0391)	(0.0398)
Ranking			0.0012	0.0011	0.0011	0.0013	0.0012	0.00124
			(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					-0.0545	-0.0943	-0.0905	-0.100
					(0.118)	(0.119)	(0.119)	(0.120)
Students abroad						0.0700**	0.0677**	0.0668**
						(0.0320)	(0.0321)	(0.0321)
R&D funding							-0.0170	-0.0139
							(0.0189)	(0.0191)
Central		0.0129	0.0744**	0.0757**	0.0756**	0.0793**	0.0811**	0.0394
		(0.0273)	(0.0328)	(0.0329)	(0.0329)	(0.0329)	(0.0329)	(0.0563)
West		-0.085**	-0.100***	-0.102***	-0.103***	-0.104***	-0.104***	-0.031
		(0.0289)	(0.0292)	(0.0293)	(0.0294)	(0.0293)	(0.0292)	(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	0.0495***	0.0783***	-0.0430	-0.0913	-0.0669	-0.0708	-0.0482	-0.0550
	(0.0146)	(0.0172)	(0.0515)	(0.0806)	(0.0963)	(0.0962)	(0.0994)	(0.100)
Observations (Total Hires)	953	953	953	953	953	953	953	953
Adj R-squared	0.077	0.0935	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*
	(0.0819)	(0.0811)	(0.0927)	(0.124)	(0.124)	(0.127)	(0.160)
Ranking		-0.00575	-0.00547	-0.00554	-0.00471	-0.00453	-0.00450
		(0.00843)	(0.00850)	(0.00852)	(0.00854)	(0.00857)	(0.00859)
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						0.0266	0.0298
						(0.0856)	(0.0893)
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 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						0.0358	0.0207
						(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

	Full Sample[ii]		Analysis Sample[iii]	
Mean Yearly Publications and Citations	Mean	SD	Mean	SD
	(1)	(2)	(3)	(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*** (0.0576)	-0.127** (0.0574)	-0.128** (0.0574)	-0.154*** (0.0581)	-0.134** (0.0548)
Male		0.127*** (0.0300)	0.127*** (0.0300)	0.146*** (0.0313)	0.104*** (0.0297)
Postdoc		0.0887*** (0.0257)	0.0864*** (0.0264)	0.0652** (0.0272)	0.0684*** (0.0257)
PhD Top 50 abroad			-0.0131 (0.0350)	0.0584 (0.0364)	0.00100 (0.0346)
BA_C9				-0.0682*** (0.0249)	0.0260 (0.0246)
Pre-Hire Publications					0.217*** (0.0166)
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*** (0.150)	0.247 (0.152)	0.250* (0.152)	0.278* (0.155)	0.0314 (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**
	(0.0702)	(0.0704)	(0.0703)	(0.0729)	(0.0646)
Male		0.109***	0.113***	0.154***	0.144***
		(0.0368)	(0.0368)	(0.0393)	(0.0348)
Postdoc		0.0901***	0.0713**	0.0419	0.0713**
		(0.0316)	(0.0324)	(0.0342)	(0.0303)
PhD Top 50 abroad			-0.109**	-0.0766*	-0.117***
			(0.0428)	(0.0457)	(0.0405)
BA_C9				-0.0296	0.0115
				(0.0313)	(0.0278)
Pre-Hire Citations					0.313***
					(0.0162)
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	0.0289
	(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

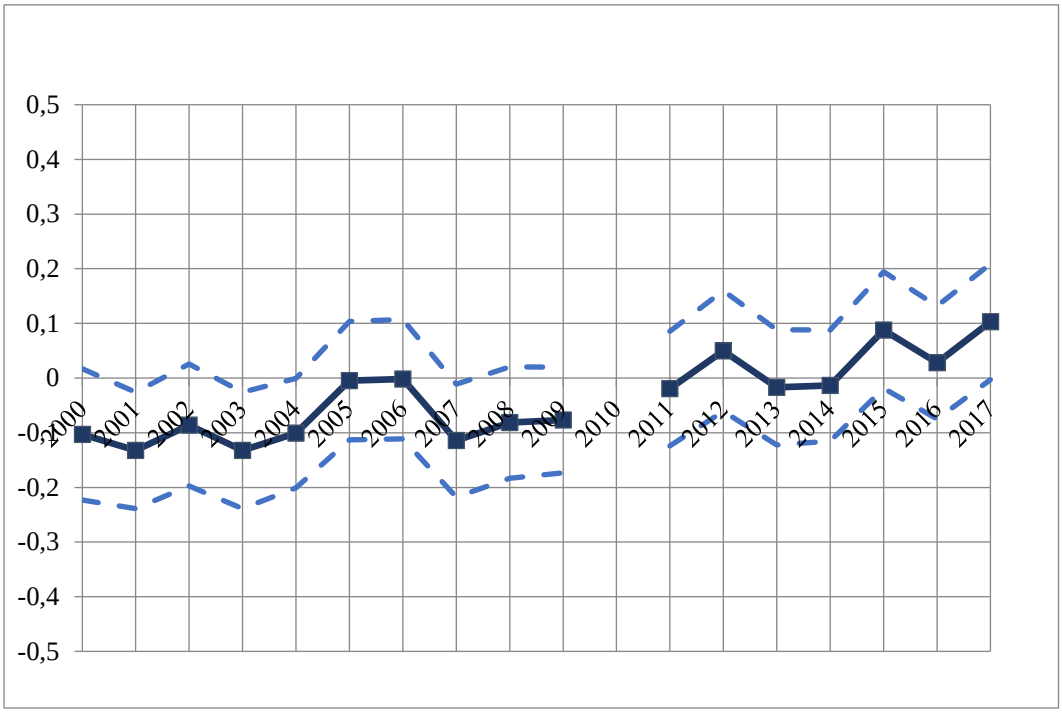
Notes: See notes to Tables 7 and 8.

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.

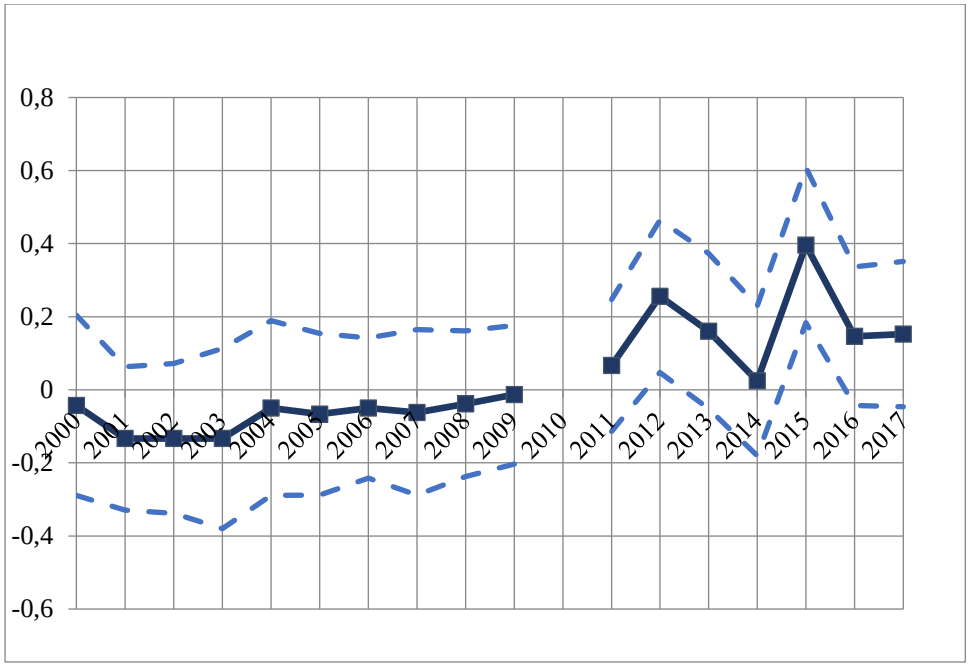
Figure 1 Proportion of Hires with a Degree from Top 50 Departments Abroad



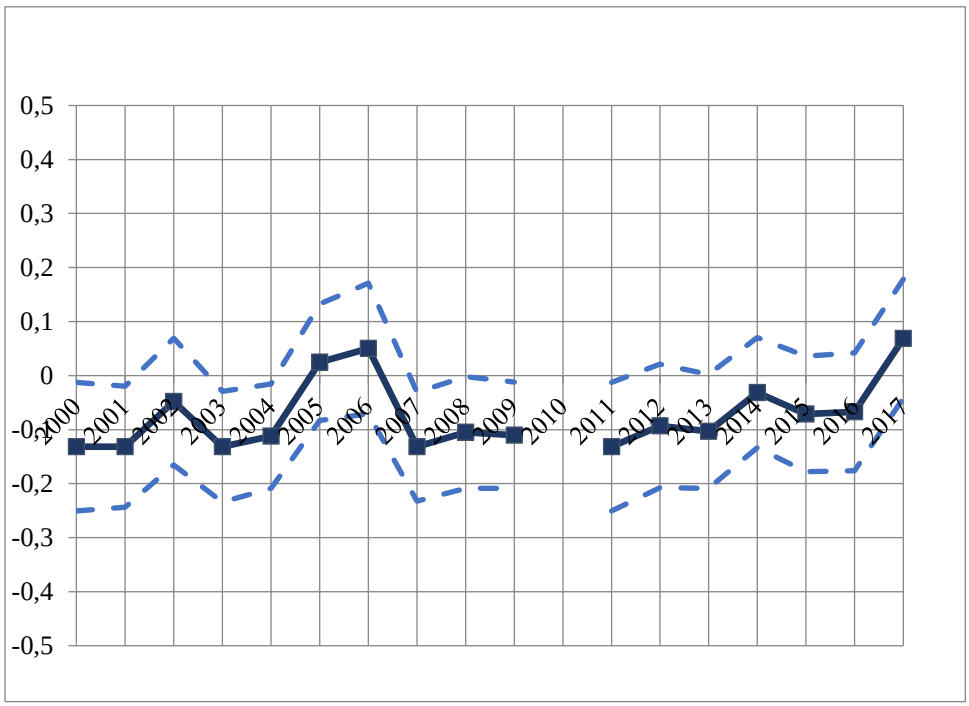
Notes: See notes to Table 1 and 1a. Figure plots estimates of β_t from equation (1) $Hire_{ict} = \beta_0 + \sum \beta_t year_{ict} + \varepsilon_{ict}$, t=2000-2009; 2011-2017, along with their 95% confidence interval. The coefficients reflect deviations from the measure of hire quality in 2010, the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

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

Panel A C9

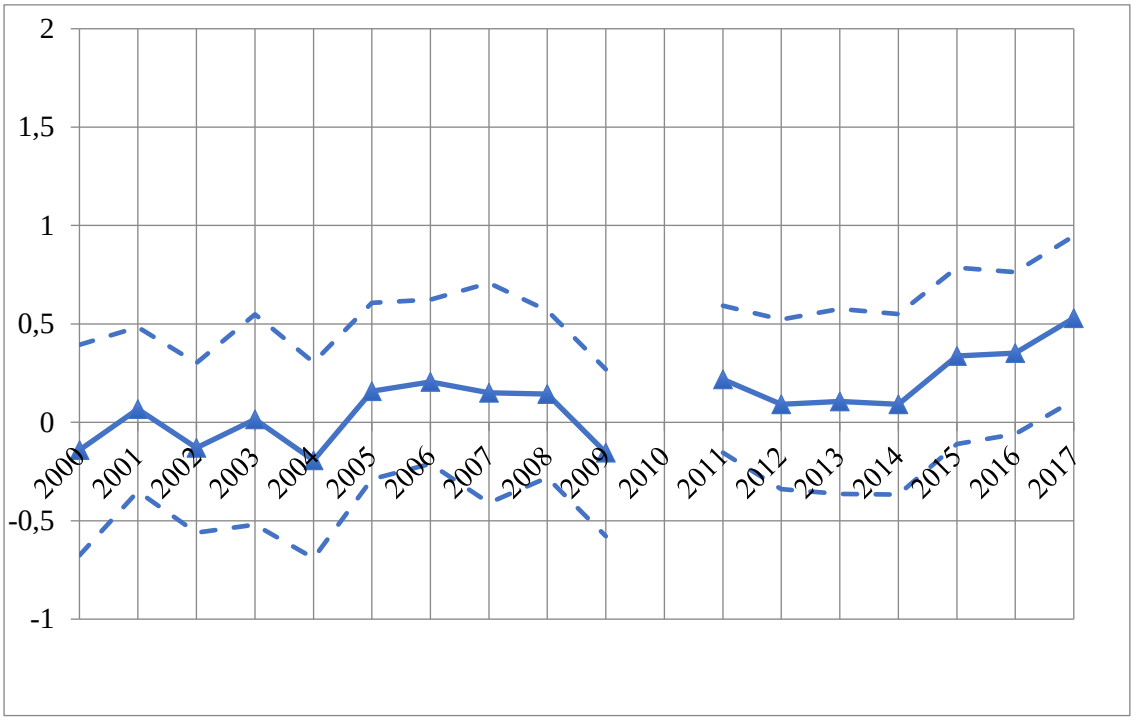


Panel B Non C9 Institutions



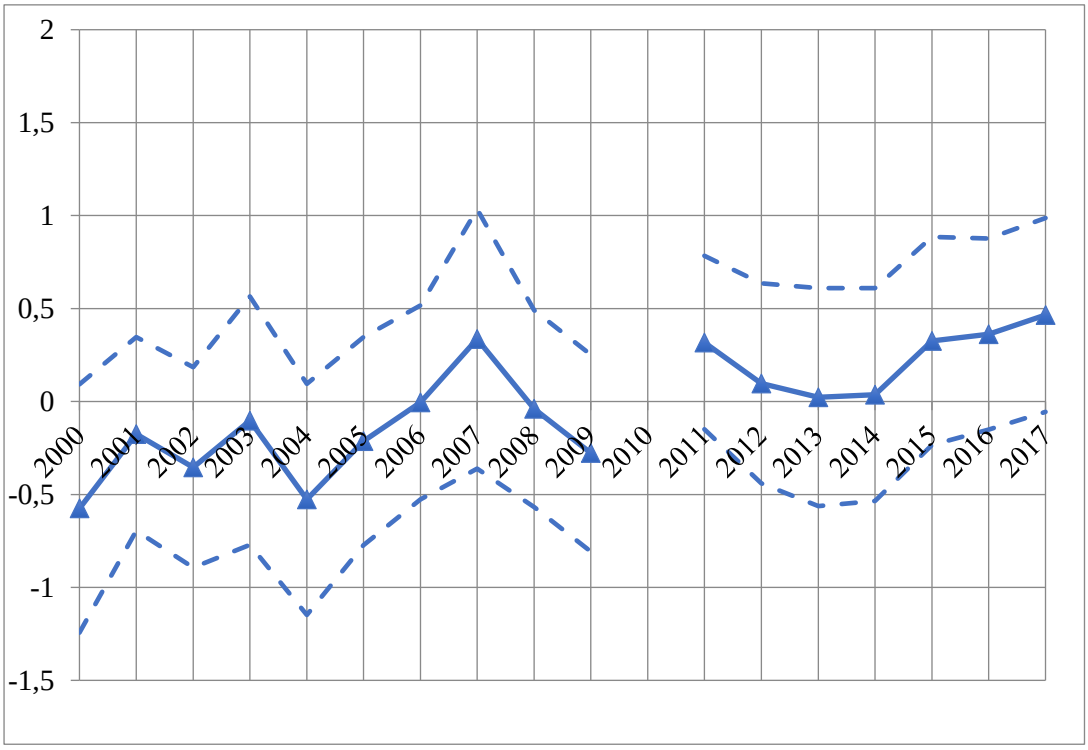
Notes: See Notes to Figure 1. C9 sample is restricted to the 7 institutions for which we have information on hire year, educational background, publication data, and related measures for at least 40 percent of faculty members.

Figure 3 Log Weighted Number of Publications C9 Institutions



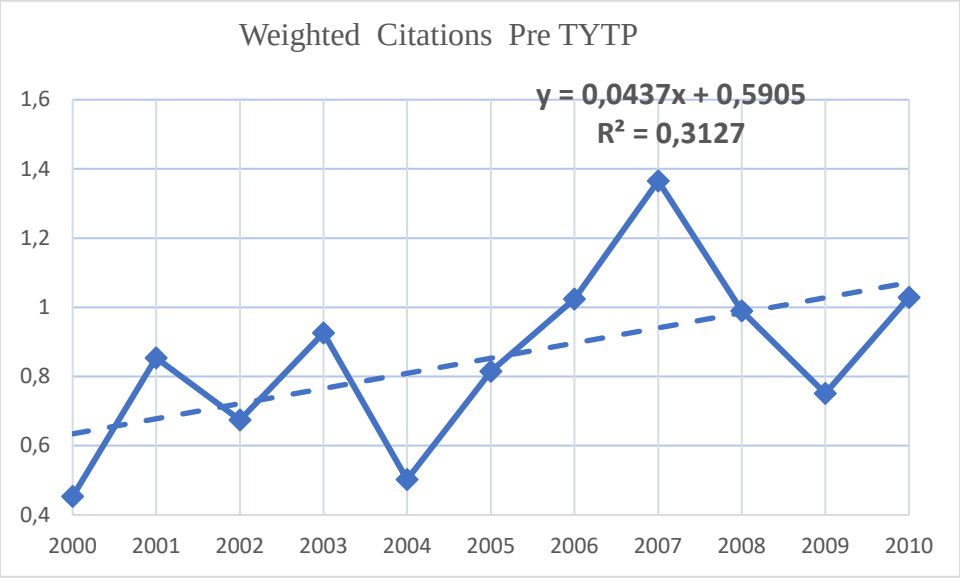
Notes: See notes to Figures 1 and 2. Figure is based on estimates from equation (5) $\log Pub_{ict} = \beta_0 + \sum \beta_t year_{ict} + \varepsilon_{ict}$; t=2000-2009; 2011-2017, along with the 95% confidence intervals. The coefficients reflect deviations from the level of hire quality in 2010, the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

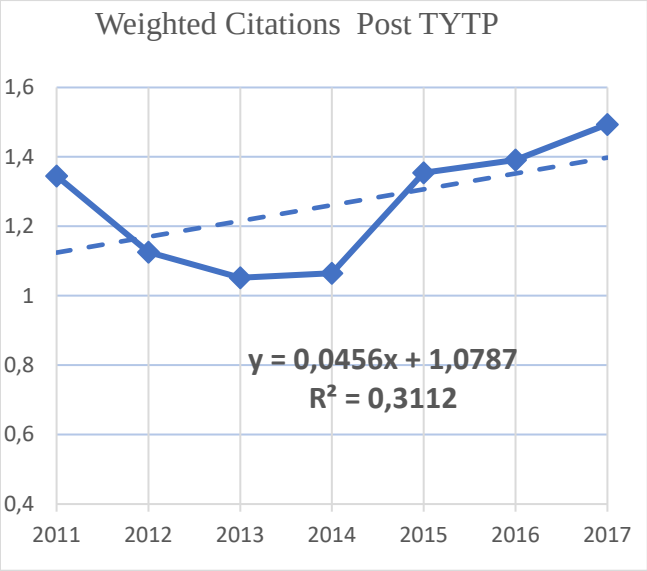
Figure 4 Log Weighted Number of Citations C9 Institutions



Notes: See notes to Figure 3.

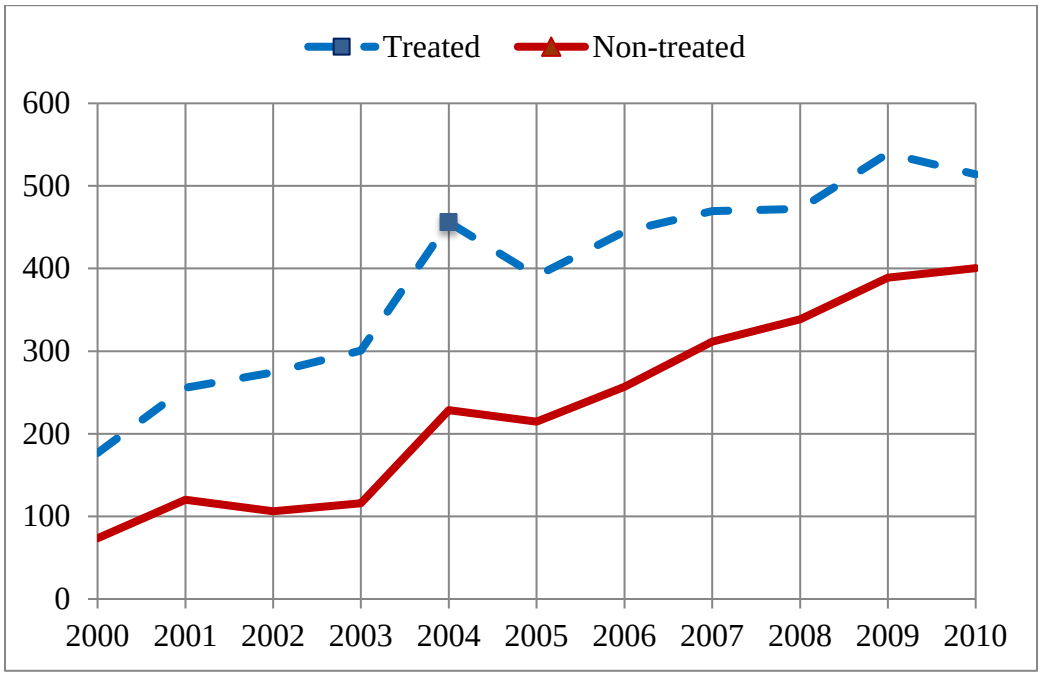
Figure 5 Log Weighted Number of Citations C9 Institutions





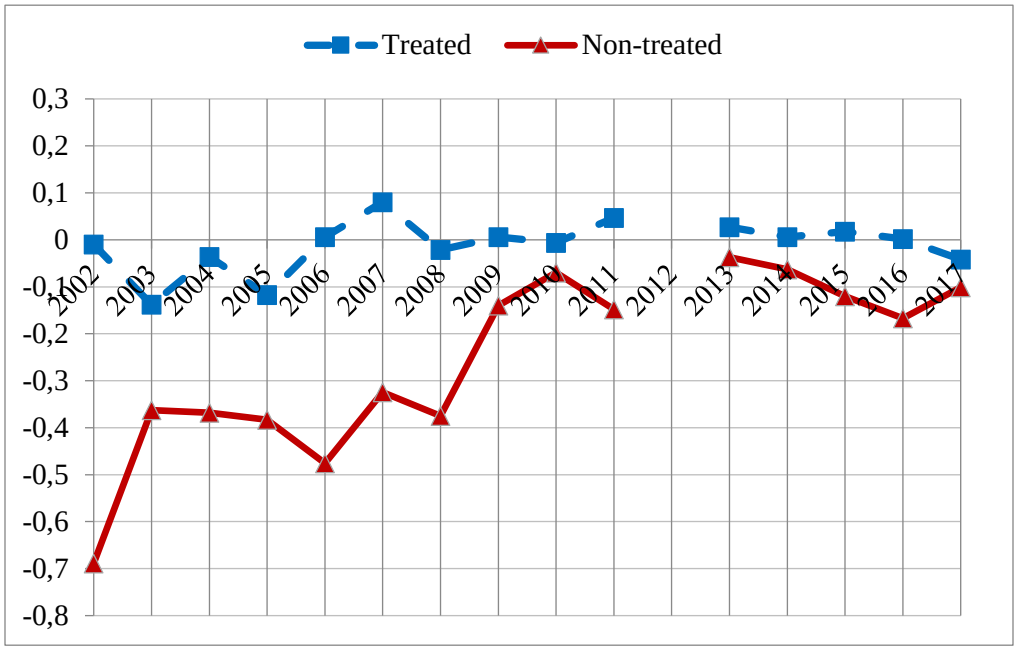
Notes: See notes to Figures 3. Figure plots estimates of from equation (5) without constant term but including dummy variable for each year, $\log Pub_{ict} = \sum \beta_t year_{ict} + \varepsilon_{ict}$; t=2000-2009; 2011-2017.

Figure 6 Publications by Mathematics Faculty in C9 Institutions



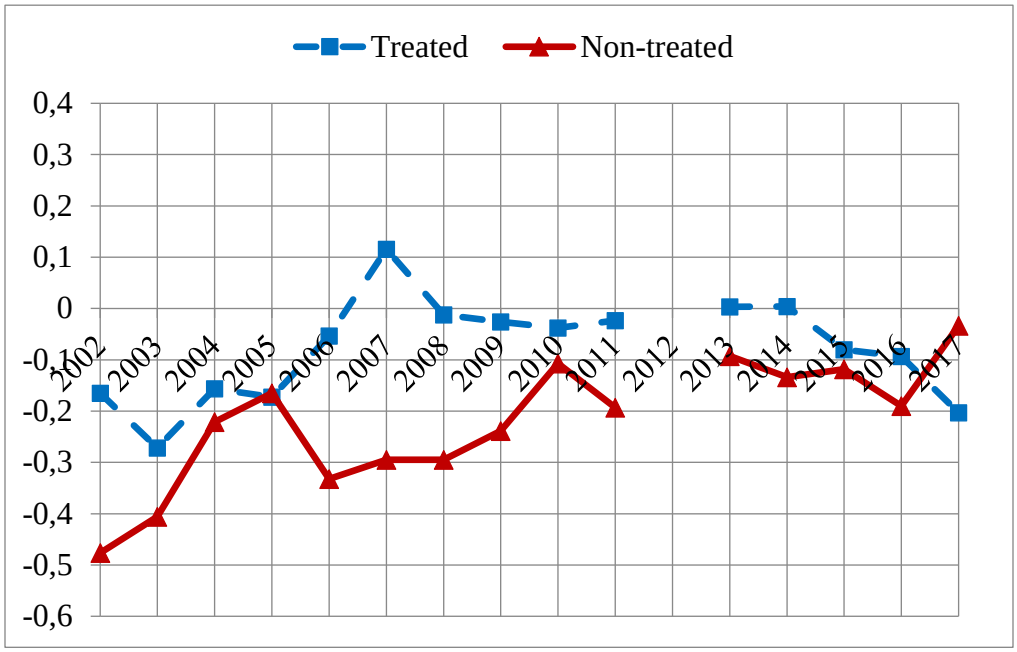
Notes: Data from Scopus. https://www.scopus.com/search/form.uri
See notes to Table 7.
i.The lines plot the average number of publications per year by faculty members in mathematics at the treated and non-treated departments.
ii. Treated departments are those in the five C9 institutions that hired some 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 Weighted Number of Publications



Notes: Figure plots estimates of β_1 from $\log Pub_{ict} = \beta_0 + \sum \beta t \quad * Pubyear_{ict} + \delta Hireyear_{ict} + \varepsilon_{ict}$, t =2002-2011; 2013-2017 for the treated and non-treated departments. The coefficients reflect deviations from the level in 2012. The dashed and solid lines plot coefficients for the treated departments and non-treated departments, respectively. The sample includes publications by those hired between 2000 and 2009 in the 7 top math departments in the C9 League. Four observations whose fields are interdisciplinary are dropped.

Figure 8 Weighted Number of Citations



Notes: See Notes to Figure 7.