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Game of Brains: Examining Researcher Brain Gain and Brain Drain and Research University Policy

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Abstract

To explore scientific mobility patterns, we leverage a rich bibliometric dataset on Taiwanese academia. We investigate the movement and productivity of 21,051 highly active researchers who published while affiliated with Taiwanese higher education institutions based on 30 years' worth of publication and affiliation records from 1991 to 2020. The analysis shows evidence of brain drain in Taiwan since the 2010s, with the U.S. the top destination for researchers moving from Taiwan (as well as the largest source of inbound researchers). China comes a close second to the U.S. as the top destination for outbound scholars. Studying how Taiwan's universities recruited talent after the country adopted the 2005 excellence initiative, we discover that the numbers of scholars recruited by World Class Universities (WCUs) and non-WCUs surpringly converge with WCUs exhibiting a dramatic decrease in new recruits. Our evidence uncovers that inbound scholars, after their move, are more productive than non-mobile colleagues; however, this effect declines over time. We discuss implications for the study of excellence initiatives, their (un)intended consequences, and mechanisms of talent circulation that greatly impact research production and research university development.

Keywords Scientific mobility · Talent competition · Research university · Higher education policy · Excellence initiatives · Taiwan

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Introduction

In the global knowledge economy, the imperative to facilitate the transfer of knowledge and the development of knowledge networks has driven policy interest toward boosting the productivity of knowledge-based industries (Jacob & Meek, 2013). Higher education, especially research universities, take center stage in knowledge creation and technological advancement (Goldin & Katz, 2010; Baker & Powell, forthcoming). The global competition for talent has been characterized by the expansion of higher education, increased mobility, and the rise of university rankings, with the concentration of knowledge power flowing where research capacity is developed and sustained (Marginson, 2010). The United States and Europe have maintained their top status as global science centers (Jacob & Meek, 2013; Powell & Dusdal, 2017), but the rise of new science powers in Asia, in particular China, and in other world regions that have prioritized building their scientific capacity, is shifting this concentration of knowledge power (Marginson, 2021).

Taiwan is among these new scientific powerhouses: by 2011, the country was producing 2.6% of the world's STEM research (Fu, 2017). Graf and Kalthaus (2018) find that Taiwan's research capacity has been catching up to the United States' and China's, the two highest-volume science systems that have also been widely documented to be key host countries for coauthors of Taiwanese researchers (Chuang & Ho, 2015; Hottenrott et al., 2021). However, the intensifying global and national competition for talent recruitment raises a policy concern: whether Taiwan can maintain its extraordinary momentum in research production while maintaining its attractiveness to leading scholars, whether junior or senior.

Hidden its international reputation, immense changes in Taiwan's policy agenda and higher education system reforms have had disparate consequences. In the 2000s, the growth of higher education led to competition for resources coupled with challenges to maintain quality (Fu, 2017). With its 50 billion-New Taiwan Dollar World-Class University Project (hereafter, WCUP), Taiwan was one of 22 countries in the world that launched "excellence initiatives" between 2002 and 2018 (Hottenrott et al., 2021). The overarching goal everywhere was to lift the nation's best universities into international prominence by providing them with substantial funding to accelerate scientific publication rates and to facilitate (inter)national competitiveness. This objective was envisioned through the recruitment of talented faculty in STEM, the establishment of research centers, and the promotion of collaborative arrangements. Yet following the WCUP, publication rates between WCUs and non-WCUs have been found to converge (Fu et al., 2020), with the latter catching up to WCU performance. Meanwhile, the trend in terms of talent recruitment between WCUs and non-WCUs has been understudied. This constitutes another gap in the literature on excellence initiatives, particularly on their impact not only on the funded but also on the non-funded universities.

Grounded in policy measures that have driven the development of Taiwanese higher education, our general objective is to construct a holistic multilevel

profile of its academia by examining the inbound and outbound movement of its researchers. While other migration studies in Taiwan have uncovered historical phases of brain drain and brain circulation (Chang, 1992; Saxenian, 2005; Nakahara, 2017; Zheng & Zhang, 2021), we here first provide a novel empirical contextualization of these concepts by tracing the publication footprint of more than 21,000 highly active researchers using a rich bibliometric dataset on publications that were (co-)authored by at least one author affiliated with a Taiwanese university. We investigate further on the institutional level by exploring the landscape of talent recruitment across universities following the country's launch in 2005 of its excellence initiative to build world-class universities. Lastly, we perform an individual-level examination of the implications of Taiwan's efforts to recruit scholars by measuring the publication contribution of its most productive inbound researchers. Through this multilevel analysis, we analyze the Taiwanese case and expand the literature on the productivity of mobile scientists and the impact of the global trend of excellence initiatives.

Literature Review

Scientific Mobility

As agents in the rise of the knowledge society where governments have increasingly turned to the contribution of highly skilled workers for economic growth, scientists have comprised a major percentage of international mobile labor (Meyer et al., 2001). Mobility among the highly educated has been demonstrated by a record of more native-born movers than stayers in major Anglophone countries (the United States, the UK, Canada, and Australia) as well as France and Germany (Dustmann & Glitz, 2011). The movement of knowledge carriers is far from random, owing to both greater opportunities brought about by rapid global economic development and the political push and pull between immigration regulations and talent recruitment policies across borders (Meyer et al., 2001). Between country pairs, evidence shows mobility to be greatly influenced by similarity in language and geographical proximity (Murray et al., 2020) and the corresponding similar prioritization of economic and resource-related factors such as R&D spending (Appelt et al., 2015).

More recently, the world has seen a reshuffling of scientists, in which North America receives mostly movement from Europe and Asia, while both Europe and Asia are welcoming a huge bulk of scientists from North America, all in contrast to the much more intracontinental nature of migration 10 years ago (Sugimoto et al., 2017). Even more crucially, researchers are less anchored to one country once they move out of their first country of publication. Affiliation patterns from bibliometric records reveal that researchers move but retain and add to existing affiliations as they change affiliations and publish (Sugimoto et al., 2017), contributing to lasting benefits to research hosts even as mobility persists.

In the context of Taiwan, extant literature on migration identified early patterns of brain drain from the 1960s through the 1980s, as most students who pursued advanced degrees in the United States chose to stay and work there (Chang,

1992). A succeeding generation of studies shows that patterns of return migration from the United States of Taiwanese researchers started in the 1990s owing to the rapid development of the Taiwanese economy (Saxenian, 2005; Velema, 2012). In the 21st century, Nakahara (2017) claims the recurrence of brain drain characterized by both skilled and non-skilled locals leaving the country for better opportunities abroad, particularly in China.

These previous studies draw from migration statistics and highlight the experiences (see Saxenian, 2005 for entrepreneurs) and research productivity (see Velema, 2012 for economists) of return migrants. Yet, there is scarce reliable empirical evidence, despite substantial anecdotal documentation on Taiwanese mobility patterns. Identifying this gap, we address the need for a more comprehensive and empirical outlook on scientific mobility by including the movement patterns of not only researchers who publish their first paper in Taiwan but also of international recruits. To answer our first research question, we conduct a national-level analysis following the publication footprint of Taiwan-affiliated researchers:

RQ1 How have scientific mobility patterns, specifically the inbound and outbound movement of researchers, in Taiwanese higher education evolved?

Excellence Initiatives and Talent Mobility

Empirical studies have established the positive impact of excellence initiatives on the performance of funded universities. Shin (2009) finds an increase in publications among funded universities under South Korea's BK 21; Zhang et al. (2013) detect improved publication rates following China's 985 Project; and Matveeva et al. (2021) find evidence of increased publications tied to Russia's Project 5-100. Meanwhile, the effects on non-funded universities have been mixed. Lovakov et al. (2021) find spillover effects of Russia's excellence initiative on the non-benefiting universities. In Germany, Esterhazy (2018) observes that the universities that failed to receive funding during the first two rounds of the excellence initiative had increased pressure to boost their academic reputation, leading to successful funding in the third round. Meanwhile, in Taiwan, Authors (2020) show that aside from the increase in quality of STEM research owed to the funding levels being well below policy expectations, the universities that received little to no funding were, surprisingly, able to outperform those with funding (Chang et al., 2009; Fu et al., 2020).

Within the logic of excellence initiatives, concentrating resources at selected universities is intended to attract the most talented researchers to conduct cutting-edge research (Altbach & Balán, 2007). As in reports of their positive impact on research performance, excellence initiatives also been confirmed to increase collaborative research indicative of larger working networks among domestic and international collaborators (Hottenrott et al., 2021). Germany's excellence initiative, for example, was reported to have brought in at least 4000 scientists from its first round in 2005 (Schiermeier, 2017). Mergele & Winkelmayer (2022) similarly find an increase in number of professors parallel to the third-party funding acquired by the German WCUs, while Möller et al. (2016) report an increased collaboration between the

university and non-university research sectors. Matveeva and Ferligoj (2020) suggest that greater researcher mobility drove the resulting growth in international research collaborations that placed Russia within global collaboration networks. Chang et al. (2009) report an increase in international collaborations and visiting international scholars to Taiwan after the WCUP was launched.

What remains underexplored is trends in mobility surrounding non-funded universities after the implementation of excellence initiatives. The same study by Lovakov et al. (2021) revealed no significant difference in number of recruited young academics between participating and non-participating universities. Taiwan's own WCUP-propelled universities were left to themselves to strategize about acquiring funding, to level up their recruitment of STEM faculty, and to create interdisciplinary research clusters (Fu, 2017), but we have yet to observe trends on the side of the universities that *did not* receive funding. Thus, to address this gap, we compare trends in talent mobility into both WCUs and non-WCUs following the WCUP. If we claim a positive impact, we should be able to observe that the funded universities, which are able to offer more incentives to bring in talented researchers to help with the institution's research performance, could recruit more highly active researchers from Taiwan or abroad. Therefore, we ask the second research question:

RQ2 Did WCUs recruit more talent after the implementation of the policy?

Research Productivity Following a Move

Researcher mobility is assumed to lead to advantages in performance, collaboration opportunities, and professional development because scientists bring social and human capital to their new universities (Fernández-Zubieta et al., 2015a). Scellato et al. (2012) assert that the significant contribution of mobile researchers to their country of destination is realized through network advantages, as is echoed by Bäker et al. (2021), who specifically attribute these advantages to acquired social rather than human capital.

Subject fields, the time following the move, and productivity levels affect the relationship between mobility and productivity differentially. STEM fields are more sensitive to better laboratory equipment and infrastructure (Ejermo et al., 2020), while non-STEM fields could be more strongly oriented to local cultural and social aspects (Horta et al., 2020). In terms of the short-term effect of moving, Fernández-Zubieta et al. (2015b) use an expansive dataset on the UK researchers and attribute the decline in productivity following a job change to adjustment costs. Among German-speaking economics and management researchers, Bäker (2015) finds a similar decline attributed to short-term losses in social and human capital. However, findings by Petersen (2018) among international physicists contest this; the increase in citation impact, collaboration network, and topic diversity among mobile scientists are not sensitive to the time following their move.

Mobility studies exploring differences in research gains across productivity levels produce equally diverse conclusions. In examining all productivity levels, Hoisl (2009) and Petersen (2018) show opposite results. Hoisl (2009) conducts a statistical

matching of 352 mobile and non-mobile German researchers based on age, research field, and educational background and finds that while multiple movers in general enjoy higher citation impact than single-movers or non-movers, the top quantile of multiple movers had the strongest advantage. Petersen (2018) similarly implements a matching of mobile and non-mobile physicists but finds otherwise; with a sample of around 26,000 physicists, the top tercile is found to be the least sensitive to mobility effects on citation impact. By comparing average values of publication count, citation count, and citation impact between mobile and non-mobile researchers who were the top 100 in their field based on number of publications, Halevi et al. (2016) show greater productivity among mobile scientists, although significant impact is shown in cases of changing affiliations within rather than across countries. Hunter et al. (2009) conduct a similar pooling process using the world's top physicists, yet find no significant difference between the productivity of movers and non-movers.

Albeit with mixed results, the empirical linkage between research mobility and productivity has indeed been significantly explored in the literature. However, we find a weakness in previous studies, which we tackle in our study. First, we establish comparability between highly productive mobile and non-mobile researchers by matching fields of specialization and duration of activity before and after the move. By doing this, we avoid simply pooling active mobile and non-mobile researchers into separate groups to compare measures of research productivity. We observe the trajectory of the highly productive mobile researchers after moving to Taiwan by distinguishing academic fields and we also show how their performance is affected in the short-term and long-term surrounding the time of their move. As such, we explore a third research question:

RQ3 With non-mobile researchers as the reference group, do inbound researchers produce more papers after moving into Taiwan? How does the trend change over time?

Methodology

Data Collection and Description

This study is conducted within the context of Taiwanese higher education, consisting of 152 universities and colleges accommodating around 1.2 million undergraduate and graduate students and hosting around 46,000 full-time faculty (Ministry of Education [MOE], 2021). Although a few universities and colleges were forced to close or merge with other universities during the 2010s, we include them to reflect the structural transformation of the higher education system. To ensure consistency in the measurement of research productivity, we include only scholars who have published original papers indexed in Elsevier's Scopus database. We define individual research productivity as the number of paper publications per person.

Ambiguities in researcher name and possible inconsistencies in institutional affiliation are two common challenges that affect individual-level bibliometric data. To address this challenge, we retrieve bibliometric data from Elsevier's Scopus

database using Rose and Kitchin's (2019) pybliometrics module. Elsevier assigns a unique author ID to each author of each article and a corresponding unique affiliation ID, granting us reliable access to any author's publication history, institutional affiliation, and other profiling data. We then retrieve the publication history of all the authors who have published an article under the ID of any Taiwanese university from 1930 to 2020.

Table 1 lists the two types of data that we use: the author's document file and affiliation history file. The document file contains records of each author's publication history, while the affiliation history file is used to capture instances of scholar mobility, based on changes in institutional affiliation.

To identify the author's research field, we link the journal's ISSN to All Science Journal Classification (ASJC) codes, which divide the 334 ASJC research fields into five major subject areas (i.e., Physical Sciences, Life Sciences, Health Sciences, Social Sciences and Humanities, and Multi-disciplinary). We assign the author's research field based on the majority of the fields of their paper publications.

From 1930 to 2020, 209,932 researchers were affiliated with universities in Taiwan and published at least one article. To avoid including research assistants or occasional researchers instead of regular researchers in our population, we remove those authors who only have one publication record. There are 118,647 researchers affiliated with Taiwanese universities and who published at least two articles. Since we are interested in highly active researchers, we further focus on those among the top 20% in their academic field based on number of publications, which amounts to 22,994 researchers. From this group, and as in our final sample, 21,051 researchers were affiliated with Taiwanese universities from 1991 to 2020. Table 2 provides descriptive statistics on the number of journal publications of individual scholars by academic field.

Among the five academic fields, physical sciences have 14,171 scholars, accounting for 67.32% of our sample, 2671 in life sciences (12.69%), 2700 in health sciences (12.83%), 1413 in social sciences (6.71%), and 96 in the multi-disciplinary fields (0.46%). On average, physical sciences researchers produced 51 papers in their publication history, life sciences researchers 50, health sciences researchers 75, social sciences researchers 30, and multi-disciplinary researchers 7.

We base the mobility status on the researchers' affiliation history. Those affiliated with a Taiwanese institution after having been affiliated with an overseas institution are classified as inbound researchers; those using an overseas affiliation after having noted affiliation with a Taiwanese institution are outbound researchers; and those who have published only with Taiwanese affiliations are non-mobile scholars.

Table 1 Structure of the data files

File	Level	Data
Document file	Article-based	Author ID, Publication ID, Affiliation IDs of all authors, Country codes of all authors, Publication Year, Journal's ISSN
Affiliation history file	Author-based	Author ID, Affiliation ID, Country code, Year

Table 2 Descriptive statistics on highly active researchers by academic field, Taiwan, 1991–2020

Academic field	Description	*N*	Journal publications	
			Mean	Std.
Physical sciences	Chemical Engineering, Chemistry, Computer Science, Earth and Planetary Sciences, Energy, Engineering, Environmental Science, Materials Science, Mathematics, Physics and Astronomy	14,171	50.77	77.43
Life sciences	Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology, Immunology and Microbiology, Neuroscience, Pharmacology, Toxicology and Pharmaceutics	2671	49.72	46.66
Health sciences	Medicine, Nursing, Veterinary Medicine, Dentistry, Health professions	2700	75	66.26
Social sciences	Arts and Humanities, Business, Management and Accounting, Decision Sciences, Economics, Econometrics and Finance, Psychology, Social Sciences	1413	30.30	27.70
Multi-disciplinary	Multi-disciplinary	96	7.11	3.55

In a given year, we perform the identification based only on the researcher's main affiliation, removing the secondary or further affiliation(s), where they might have stayed for a short period of time, to avoid duplicate counts. We assign as mobility year the year they switched their affiliation type (from Taiwanese to overseas or vice versa) in their publications. Table 3 elaborates the definitions of each mobility type: inbound, outbound, and non-mobile. We identify 4175 inbound researchers and 254 outbound researchers. Inbound scholars account for nearly 20% of the total sample, outbound scholars account for only 1.21%, and 16,682 non-mobile scholars comprise nearly four-fifths of our sample.

Estimation Strategy

We explore talent recruitment surrounding the 2005 WCUP, that is the number of new recruits in STEM+ disciplines between the baseline period (5 years before) and the follow-up period (5 years after) in WCUs and non-WCUs. In particular, we employ a two-sample t test estimation on the two groups and observe the change before and after the period studied. Following Authors (2020), we assign to the WCU group the 10 universities chosen by the initiative out of 32 applicants and which were thus awarded significant supplementary research funding. Of the remaining 22 universities, we assign to the non-WCU reference group the 14 initially most research-intensive, measured by number of journal publications. We also estimate whether inbound researchers are more productive in terms of publications during the follow-up period (6 years after moving to Taiwan) compared to the baseline period (5 years before moving to Taiwan), with non-mobiles as the reference group. To ensure the comparability of the researchers in the two groups, we apply a criterion for selecting inbound scholars moving to Taiwanese universities from 2001 to 2012 and non-mobile scholars who have the same publication history. For example, a researcher who moved to Taiwan in 2005 and has published five consecutive years before 2005 and six consecutive years after 2005 is sorted into the inbound group. To sort non-mobile scholars at the same career stage into the non-mobile reference group, we select those who also published for five consecutive years before and six consecutive years after 2005. This arrangement ensures that the inbound group and reference non-mobile group, both in the top 20% of the most productive researchers by their number of publications, not only have the same level of productivity in their own academic fields but are also at the same career stage.

Table 3 Definition of highly active researchers by type of mobility, Taiwan, 1991–2020

Type of mobility	Definition	Number
Inbound	With overseas affiliation before moving to a Taiwanese institution	4175
Outbound	With overseas affiliation after leaving a Taiwanese institution	254
Non-mobile	Without overseas affiliation experience	16,682

60 researchers experienced both inbound and outbound mobility.

Since there has not been an established window of lagged effect on talent recruitment following the implementation of excellence initiatives, we investigate the number of recruited scholars given 2-year, 3-year, and 4-year lags to check the robustness of our empirical findings. As is common in studies of research production, we lag our dependent variables by 2 years to account for the time lag in getting a research paper published (Shin, 2009; Zhang et al., 2013). We calculate the number of recruits by each university during the baseline and follow-up period to present the WCUs and non-WCUs' performance on talent recruitment. We also calculate the number of publications by individual researchers during the baseline and follow-up period to reflect the mobile and non-mobile scholars' research productivity. Table 4 presents a descriptive summary on talent recruits and publications before and after the period studied in our estimations.

Results and Discussion

Historical Trend by Brain Gain and Brain Drain at the National Level

To answer our first research question, we compute the number of inbound scholars and outbound scholars annually from 1991 to 2020. Figure 1 shows the historical trend of transnational mobility among highly active researchers. The white bar indicates the number of inbound researchers per year from 1991 to 2020, while the black bar denotes outbound. The trend shows that inbound movement dominated transnational mobility before the 2010s. In 1991, 81 highly active researchers were recruited from overseas institutions. Inbound movement reached its peak in

Table 4 Descriptive summary of the outcome variables

Level	Outcome variables	WCUs/inbound			Non-WCUs/non-mobile		
		N	Mean	Std.	*N*	Mean	Std.
Institutional	STEM+ recruits-2-year lag-before	10	365.7	65.5	14	105.8	8.8
	STEM+ recruits-2-year lag-after	10	326.6	61.3	14	100.9	9.8
	STEM+ recruits-3-year lag-before	10	381.4	67.2	14	109.6	7.8
	STEM+ recruits-3-year lag-after	10	298.8	55.1	14	94.8	11.2
	STEM+ recruits-4-year lag-before	10	378.2	66.3	14	109.2	8.2
	STEM+ RECRUITS-4-year lag-after	10	268.2	48.8	14	87.3	12.1
Individual	Publications-physical-before	296	10.8	0.6	4179	10.9	0.1
	Publications-physical-after	296	25.0	1.3	4179	19.6	0.3
	Publications-life-before	84	7.0	0.5	956	8.1	0.2
	Publications-life-after	84	16.5	0.1	956	16.2	0.4
	Publications-health-before	34	9.6	1.3	673	12.0	0.4
	Publications-health-after	34	23.0	2.9	673	22.8	0.7
	Publications-social-before	19	4.8	1.0	479	7.3	0.3
	Publications-social-after	19	10.6	2.2	479	12.1	0.5

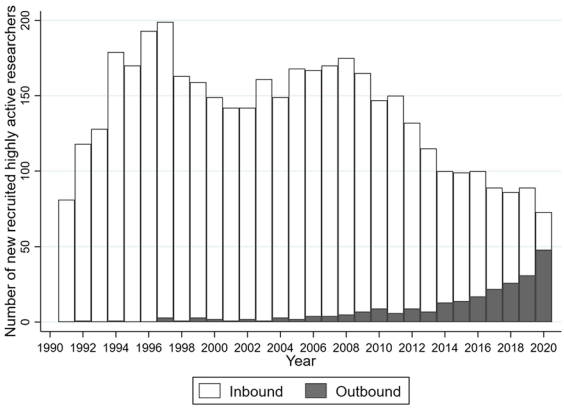

Fig. 1 Historical trends of brain gain and brain drain of highly active researchers, Taiwan, 1991–2020

1997 when 199 researchers moved to Taiwan and only three left. Inbound mobility remained stable until 2009 and started decreasing every year thereafter. During the first 19 years, the ratio of inbound to outbound scholars was 1:0.013, with 2978 inbound scholars compared to only 40 outbound.

The landscape of talent recruitment has changed since the 2010s, with the number of inbound scholars decreasing every year. In 2010, there were 147 inbound scholars. By 2020, the number had decreased to 73, slightly more than a third of the volume in 1997. On the other hand, outbound movement became more apparent. In 2010, the number of outbound scholars was just 9. The upward trend continually climbed over the decade and reached 48 by 2020. During the last 11 years, the total number of inbound scholars was 1180 and outbound 202, reducing the gap between the two types of scientific mobility to 1:0.17.

On the global level, this rapidly decreasing ratio between outbound and inbound mobility echoes global changes that underscore increased mobility between world regions, diversification of prospective research destinations, and more competition for Taiwan as an increasingly attractive research hub. Most importantly, within Taiwan, these findings reflect grave changes within the talent supply system that, if allowed to persist at the same rate over the coming years, ultimately will mean a thinning stream of highly active scholars left to sustain Taiwan's research capacity. We explore further details of these mobility patterns by investigating from which countries inbound talent comes to Taiwan as well as those to which outbound talents move.

The stream of inbound scholars to Taiwan shows its strong connection with Anglo-Saxon countries. Table 5 details the countries of origin of inbound scholars and countries of destination for outbound scholars. Among 4175 inbound scholars, the majority has been affiliated with institutions in Anglo-Saxon countries (80%), followed by Asian countries (14%), and European countries (4.4%). On the country level, the United States accounts for the origin of 72% of inbound scholars, confirming either the attractiveness of Taiwan to its native researchers or a heavy stream of already-active US-trained Taiwanese scientists returning. The UK comes in second, although with a comparatively meager 5.3% of inbound researchers, or

Table 5 Top source and destination countries of highly active scholars from/to Taiwan, by region and country

Origin country	Inbound		Destination country	Outbound	
	N	%		*N*	%
Anglo-Saxon	3377	80.4	Anglo-Saxon	93	34.1
US	3033	72.2	US	80	29.4
UK	223	5.3	UK	2	0.7
Canada	72	1.7	Canada	6	2.2
Asia	597	14.2	Asia	133	48.8
Japan	177	4.2	China	77	28.3
India	152	3.6	Japan	15	5.5
China	122	2.9	Viet Nam	6	2.2
Europe	183	4.4	Europe	26	9.5
Germany	60	1.4	Germany	7	2.5
France	28	0.7	France	3	1.1
Netherlands	16	0.4	Belgium	1	0.3
Rest of world			Rest of world		
Total	4175		Total	254	

223 researchers. In Asia, Japan sends the biggest share of talent to Taiwan (4.2% of inbound mobility).

The case of outbound scholars paints a much more regionally diverse picture, that is, when it comes to talent leaving Taiwan, Asia is favored over Anglo-Saxon countries. Among 254 outbound scholars, half move to other Asian countries, followed by Anglo-Saxon countries (34%), and European countries (9.5%). On the country level, Taiwan maintains the strongest connection to the United States as the recipient of 29% of outbound talent, rendering it an important partner in terms of scientific mobility. However, China, which sends only 3% of inbound scholars to Taiwan, comes a close second as the biggest destination of its talent, receiving 28% of outbound scholars from Taiwan.

Taiwan's strong associations with the United States and China as destination countries are corroborated by its strong relationship with them in terms of international research collaborations (Hottenrott et al., 2021). This points primarily to the consistently pivotal role of the United States as a destination not only for Taiwanese Ph.D. seekers—as was the trend since the 1980s—but also for highly active researchers who have already published with Taiwanese collaborators. Furthermore, and equally important, the long history of researcher mobility from the United States to Taiwan represents a once-reliable means of exchange of brains and an important bilateral relationship to which policymakers must pay attention, even more so as the volume steadily decreases.

Meanwhile, significant movement from Taiwan to China may be a testament to mobility anchored in language and geographical proximity (Murray et al., 2020) and better incentives and opportunities offered by China to Taiwanese (Nakahara, 2017). Save for these, Taiwan's losing talent to China might also be owed to the latter's growing importance in global research and as a prime destination for scholars

globally, most importantly from the United States (Chinchilla-Rodríguez et al., 2018).

Convergence in Scholar Recruitment

Our second research question attempts to address whether WCU universities recruited more highly active researchers in STEM+ fields before the excellence initiative was launched. Given the intentions and concrete goals of the WCUP, we would expect that the number of highly active researchers from the already-heavily resourced WCUs would be maintained or extended following the provision of supplemental funding. However, our estimation does not support this hypothesis.

As shown in Table 6, given the 2-year lag, during the baseline period, the WCUs on average recruited 365 new highly active researchers in 5 years, whereas non-WCUs recruited only 105. The difference between two groups is 259, which is statistically significant. However, during the follow-up period, the WCUs recruited 326 new highly active researchers and non-WCUs recruited 100. The difference between two groups is reduced to 225, and this is still statistically significant. Given 3-year and 4-year lags, this between-group difference decreases to 203 and 180, respectively. Following a robustness check, we find that instead of recruiting more highly active researchers, WCUs recruited less talent after the policy implementation, further reducing the difference in talent recruitment between the two university groups through the succeeding period.

Figure 2 depicts the convergence in number of new recruits between the two groups, the trajectory of WCUs as denoted by the dashed line, the trajectory of non-WCUs by the dashed-dotted line, and the annual difference between the two groups by the solid line. Prior to policy implementation, on average, WCUs stably increased their new recruits from 61 in 2001 and reached a peak of 82 in 2004. The momentum comes to an apparent decline in 2006 and does not rebound.

After 2006, the number of new recruits at WCUs immediately shrank. These data illustrate that the policy goal of recruiting more well-renowned scholars to build the

Table 6 Two-sample t test estimates on the number of new recruits between WCUs and non-WCUs by time lags

Period	Type	*N*	2-year lag Mean (std. error)	3-year lag Mean (std. error)	4-year lag Mean (std. error)
Baseline	WCUs	10	365.700 (65.586)	381.400 (67.232)	378.200 (66.389)
	Non-WCUs	14	105.857 (8.836)	109.642 (7.854)	109.214 (8.204)
	Difference		259.842 (55.923)	271.757 (57.074)	268.985 (56.449)
	t-value		4.646***	4.761***	4.765***
Follow-up	WCUs	10	326.600 (61.394)	298.800 (55.154)	268.200 (48.806)
	Non-WCUs	14	100.928 (9.849)	94.857 (11.245)	87.357 (12.162)
	Difference		225.671 (52.735)	203.942 (48.090)	180.842 (43.362)
	t-value		4.279***	4.240***	4.170***

$^{+}p < 0.10$, $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

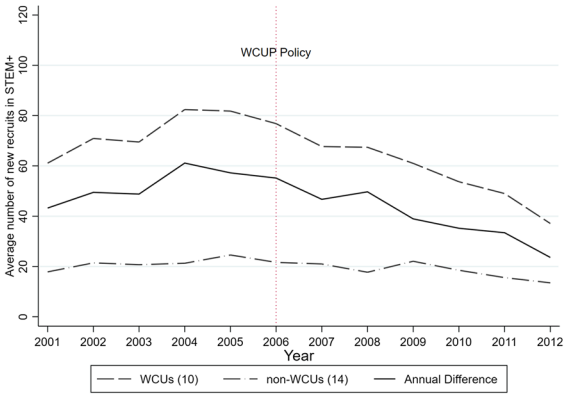

Fig. 2 Comparison of average number of new recruits in STEM+ among universities (WCUs and non-WCUs), Taiwan, 2001–12. *Note*: 2-year lag applied

reputation of world-class universities was not achieved. In 2006, WCUs recruit, on average, 77 highly active researchers. In 2012, WCUs, on average, recruit only 37 highly active researchers, far lower than the value from 10 years prior. Conversely, non-WCUs do not seem deterred by the WCUP; instead, they maintain their volume of recruits at around 20 new recruits.

A remarkable, unintended impact of Taiwan's excellence initiative then points to a converging number of recruits between the two groups of universities. The failure of the implementation of the excellence initiative to translate into new recruits for WCUs alludes to the possibility that recruiting top talent might not have been a priority for WCU administrations in their strategies to improve their research. Even more so, it did not facilitate their ability to maintain the number of recruits they successfully attracted before the policy, which questions recruitment and other organization-level human resource efforts that could have been provided greater support of increased research production. Even more surprising is that while the WCUs recorded fewer new recruits who could contribute their research output, the non-WCUs benefitted from the WCUP with even stronger increase in research performance, a wholly unintended result (Chang et al., 2009; Fu et al., 2020). This highlights a disconnect between the general policy premise of excellence initiatives and organization-level activities to implement this policy and respond to its programs, as decisions were more freely made by the WCUs. We note that the case of the WCUs mirrors our national-level data (see Figure 1) of greater mobility out than into Taiwan.

Fading Superiority in Research Productivity

The third research question concerns the publication performance of inbound researchers after their move to Taiwan. As displayed in Table 7, the estimates of the two-sample t test provide partial confirmation of the assumption that mobile scholars are more productive than their non-mobile colleagues. We classify researchers into four academic fields based on their area of publication. In physical sciences, before moving to Taiwan, inbound scholars have no statistical difference to non-mobile scholars in terms of their total publication in 5 years;

Table 7 Two-sample t test estimates on the number of journal publications between inbound and non-mobile scholars by academic field

Academic field		Physical sciences		Life sciences	
Period	Type	*N*	Mean (std. error)	*N*	Mean (std. error)
Baseline	Inbound	296	10.851 (0.600)	84	7.059 (0.522)
	Non-mobile	4179	10.909 (0.187)	956	8.143 (0.245)
	Difference		− 0.057 (0.722)		− 1.083 (0.843)
	t-value		− 0.080		− 1.284
Follow-up	Inbound	296	25.081 (1.369)	84	16.547 (1.173)
	Non-mobile	4179	19.670 (0.341)	956	16.297 (0.486)
	Difference		5.411 (1.332)		0.250 (1.679)
	t-value		4.060***		0.149
Academic field		Health sciences		Social sciences	
Period	Type	*N*	Mean (std. error)	*N*	Mean (std. error)
Baseline	Inbound	34	9.617 (1.361)	19	4.842 (1.071)
	Non-mobile	673	12.053 (0.421)	479	7.396 (0.320)
	Difference		− 2.435 (1.900)		− 2.554 (1.626)
	t-value		− 1.281		− 1.570
Follow-up	Inbound	34	23 (2.974)	19	10.631 (2.280)
	Non-mobile	673	22.852 (0.710)	479	12.164 (0.522)
	Difference		0.147 (3.230)		− 1.533 (2.664)
	t-value		0.045		− 0.575

$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

however, inbound scholars produce 5.4 more papers on average than their non-mobile colleagues in the 6 years following their move to Taiwan. In life sciences and health sciences, although the inbound scholars produced less papers than their non-mobile colleagues before moving to Taiwan and more papers after moving to Taiwan, the difference between the two groups is not statistically significant. In social sciences, inbound scholars on average produced less papers than their non-mobile colleagues in both the baseline period and after moving to Taiwan, which could be attributable to the field's lesser sensitivity to a change of physical location than the hard sciences (Ejermo et al., 2020), but more sample cases are needed to confirm this result.

Although the differences between two groups during the baseline and follow-up period are not statistically significant, except in physical sciences, the observation based on the average publication rates by two groups by year helps to highlight changes over time. Figure 3 depicts the trajectory of research productivity by type of scientific mobility and academic field. There are at least three notable points.

First, the trend follows an upward direction, demonstrating that the two types of mobility follow a growth trend. Second, we observe no superiority among

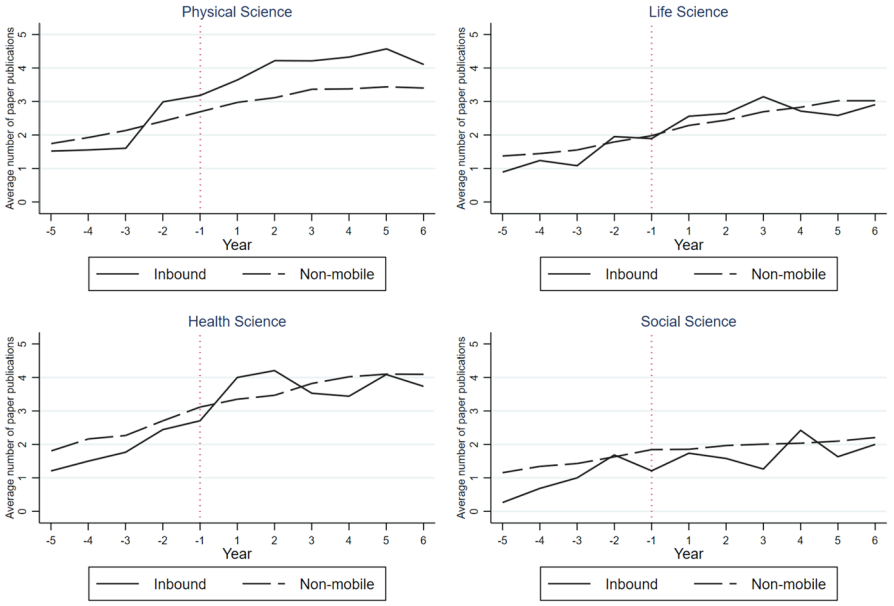

Fig. 3 Comparison of average number of publications by inbound and non-mobile researchers, by academic field, Taiwan. *Note*: 2-year lag applied

inbound scholars before their move to Taiwan compared to their non-mobile colleagues. Except in physical sciences, inbound scholars on average produce fewer publications than non-mobiles at least 2 years before moving to Taiwan. However, by the first year following their move, varying degrees of divergence between the production of inbound and non-mobile scholars are observed in physical sciences, life sciences, and health sciences. Because our matching process controls for research activity before and after the researcher's move (and lack of move for non-mobiles), we isolate mobility to Taiwan as a determining event; differences across fields become visible. Within the first years of moving to Taiwan, inbound scholars produce more papers than their non-mobile colleagues. The divergence between the two groups is more pronounced in the physical sciences, which attests to the increase in productivity attributed to the mobility of scientists (Hoisl, 2009; Sugimoto et al., 2017).

It is striking that such divergence between the two groups decreases as inbound scholars the longer they remain in Taiwan. In physical sciences, this advantage begins to decrease in the sixth year, in life sciences in the fourth year, and in health sciences in the third year. It is possible that social and human capital or other advantages accumulated from their overseas experience might give them a head start in their first years in Taiwan (Fernández-Zubieta et al., 2015a; Scellato et al., 2012). However, the longer they stay, the more these advantages that are beneficial for scientific production lessen, as the researchers become embedded in the institutionalized environment. In this regard, inbound researchers collectively being more productive upon moving to Taiwan yet eventually showing performance decline could

provide insight to both Taiwan's research boosting capacity, at least in number of publications, and possible local institutional (Allison & Long, 1990) or laboratory (Carayol & Matt, 2004) effects, whether on returning Taiwanese or internationally mobile scholars. The drop in productivity suggests either the presence of an inhibiting factor to their momentum or the disappearance of the impetus of the initial spike in their performance. More importantly, the sharper spike yet slower decline in productivity in the physical sciences is a stark contrast that emphasizes field differences and affirms Taiwan's capacity as a destination for mobile physical scientists.

Limitations

Our empirical findings present several limitations. Because we rely on publication addresses in tracing the movement of researchers, our research is limited to tagging the affiliation of the first publication as their point of origin. For this, we checked the curricula vitae of 50 randomly selected researchers and found that our estimation of their location reflected their affiliation history in Elsevier's Scopus. However, publication records as indicators of mobility do not guarantee the accuracy of the information on the researchers' year of mobility. In other words, we do not have information on a given year if a researcher did not publish during that year, yet this issue should be minor because our study focuses on highly active researchers. Furthermore, using bibliometric data to reflect the mobility of scholars has been adopted as a good alternative approach (Sugimoto et al., 2017) when international administrative data are not available.

Second, although we choose the reference group of universities or researchers based on strict criteria, parallel trends unobserved before the given time period prevent us from making a causal argument. We therefore present in the empirical findings the average difference before and after the given time period, although not attributable to the event. Nonetheless, the trajectory of the two groups can still supplement this methodological weakness and help provide a longitudinal depiction of patterns surrounding the WCU policy and scholars' mobility to Taiwan.

Conclusions and Implications

We uncover the historical trends of researcher mobility within Taiwanese academia, investigate talent recruitment surrounding the 2005 excellence initiative, and provide empirical evidence to show the influence of mobility on the rising research productivity of inbound scholars to Taiwan. The contribution of our findings lies in our empirical identification of key countries providing and benefitting from talent flowing to and from Taiwan. We show that the country has witnessed a steep decline in inbound talent and an increase in outbound talent. The United States remains an important mobility partner—as both the biggest sender and recipient of talent to and from Taiwan. By contrast, China's importance is tied to draining talent from Taiwan. Our findings diversify the literature on the impact of excellence initiatives. Surprisingly, funded universities recruited fewer talents following funding than before. This

questions the impact of implementation of excellence initiatives that support competition yet are rather flexible in the range of means, that is, if universities are left unsupported to develop their strategies most likely to lead to success. The presented case of Taiwan could prove to be valuable in investigating trends, and especially revealing unintended consequences, in other country case studies of excellence initiative policies. Additionally, we confirm improved productivity among researchers who are mobile, but underscore differences across fields. There is merit in exploring Taiwan as a hub for physical sciences research and this offers interesting comparisons with other fields to analyze specific effects on the relationship between mobility and research productivity. Future analyses on scientific mobility and productivity will surely benefit from larger datasets to track highly productive mobile and non-mobile scientists in other fields.

Our findings further entail implications on talent recruitment and retention. First, a key to maintaining the vitality of Taiwan as a research powerhouse is to bolster the incoming stream of talent and simultaneously support those scientists who are most likely to move and to remain in Taiwan. This is particularly crucial as Taiwan has faced internal and external challenges to strengthen its supply of talent. Domestically, low birth rates and an increasingly aging society (MOE, 2013) have posed a threat to the volume of education seekers and consequently the operation of higher education institutions (Chen, 2021). Between 2011 and 2020, six universities either closed or merged, while the amount of full-time faculty positions has shrunk from 50,000 in 2011 to 46,000 in 2020 (MOE, 2021). Outside Taiwan, growing higher education systems in neighboring Asian countries like China have been strongly committed to attracting international researchers (Nakahara, 2017; Lu & Zhang, 2015). The emerging inversion between inbound and outbound mobility to and from Taiwan since the 2010s is the latest indicator of lack of ability to sustain its extraordinary growth in research capacity. Our study provides direct evidence that should be a matter of great concern to national policymakers hoping to reinforce Taiwan's higher education and science system.

Second, the failure of WCUs to translate more resources provided by additional policy initiatives to increase top talent potentially contributes to the lack of dramatic growth in their scientific production after the implementation of the WCUP (Fu et al., 2020). Additional monetary incentives were provided that were expected to increase research capacity and output among WCUs. Although these resources might have bolstered their ability to recruit top-performing scholars from abroad, other structural issues arising from institutional governance seem likely to have prevented effective talent recruitment. Zheng and Zhang (2021)'s qualitative study documents that red tape in the recruitment process and the prevalence of nepotism drive Taiwanese PhD holders to choose to stay in the United States. Their interviewees further identify threatened political instability (particularly in recent years) and lack of long-term planning as personal reasons for not coming returning to Taiwan. Ultimately, the challenge of establishing—and maintaining—world class universities calls for not only an abundance of resources but also strong university governance and effective clustering of talent (Salmi, 2009).

Additionally, the trajectory of research productivity observed among inbound researchers to Taiwan presents two important implications. First, the productivity

boost among inbound researchers immediately following their move supports the imperative for Taiwan to scale up its participation in truly global talent competition. Second, the eventual decline in inbound scholars' performance suggests the need for the development of a recruitment package that not only brings them to Taiwan but also sustains the momentum of their productivity, especially after some time spent in domestic organizations. Ultimately, these implications raise crucial policy questions about ensuring the sustained research capacity of the national innovation system.

Finally, our study provides an evaluation of Taiwan's talent supply and key instruments driving higher education and research policy. If Taiwan is to learn from China as its biggest competitor in attracting talent to contribute to raising the quality of the whole research system, a viable option is to capitalize on the opportunities for international collaboration available to researchers currently in Taiwan and Taiwanese researchers abroad (Fangmeng, 2016). By largely ignoring what transpires in non-WCUs, the WCUP reflects the absence of a system-wide perspective on institutional and organizational conditions needed to maintain and develop Taiwan's national research capacity. A step toward improving not only the research capacity of WCUs but of the national system as a whole would be to encourage more research collaborations between inbound researchers and non-mobile researchers, especially before the eventual decline in their productivity level. Maximizing the impact of recruiting top talent to Taiwan entails enabling them to easily access the tools they need to push their productive research agendas and to integrate them within domestic research networks to positively impact the whole scientific community.

Extending this line of inquiry, further research building upon our findings could examine opportunities to navigate recruitment mechanisms between WCUs and non-WCUs through in-depth interviews with university representatives to provide insights into changing recruitment patterns as a result of the excellence initiative and other responses to (potential) funding from the WCUP. On the ground, field differences in productivity trajectories among inbound talent could be explored, especially factors in research production induced by national policy, institutional, department, or individual drivers. Studies could investigate the effects on productivity across researchers and institutions of networks and collaborations and the corresponding impact on research (output) alongside charting the trajectories of mobile scientists and their career production. Overall, since our findings measure the magnitude of scientific mobility in Taiwan, there is merit to investigate underlying risk factors of moving to other countries and determining, at national level, why Taiwan has witnessed a sharp decline in inbound talent and what, if not excellence initiatives, could enable its scientific talents to thrive effectively and sustainably.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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