Increased academic performance and prolonged career duration among Taiwanese academic faculty in ecology and evolutionary biology

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Abstract:
Academic job markets have become increasingly challenging worldwide, yet it remains poorly characterized how competitively-successful candidates should be and what the underlying determinants of their success are. Focusing on ecology and evolutionary biology, we analyzed the academic performance (measured as h-index) as well as the duration required to land a faculty position and promotion to full professor of 140 principal investigators (PI) over the past 34 years in Taiwan. We found that faculty members had higher performance and longer duration before recruitment as a new PI more recently. Performance before promotion remained stable, whereas the duration increased over time. The origin and prestige of doctorate had no effect on the performance or duration neither before recruitment nor promotion. We also found that the difference in performance before and after recruitment decreased in recent years, with PIs recruited earlier having higher performance after getting the job compared with those recruited later. While PIs performed equally well before and after recruitment irrespective of doctorate origin, those with domestic doctorates showed a decrease in performance after promotion compared to their counterparts with foreign doctorates. Our findings highlight the increasingly crucial role of academic performance, rather than PhD degree itself, in determining academic success.

Introduction:
The academic job market has been increasingly competitive in many fields of science, technology, engineering, and mathematics (STEM) [1–3], with more PhDs produced but vacancies for tenure-track academic positions remaining constant in the past four decades [4,5]. For example, in the US, only 7.6% new PhDs in life sciences landed tenure-track positions within three years after graduation in 2010; this surplus of PhD supply has widely expanded to other STEM fields [6].

The intensifying competition for tenure-track positions, due to disproportionately high numbers of accumulating applicants per position [5], has resulted in higher expectations for academic performance shaped by a “publish or perish” culture [7]. A survey of evolutionary biologists recruited as junior researchers at the National Centre for Scientific Research (CNRS) in France showed that academics recruited in 2013 published nearly twice as many papers as those recruited in 2005 did [8]. Although the minimum education requirement for a tenure-track position is having a PhD degree, it has become increasingly frequent for applicants to have one or even more postdoctoral appointments. Consequently, many STEM PhDs work as postdoctoral researchers for a prolonged period and wait for future opportunities until they are competitive enough in the academic job market [9], whereas some turn to alternative careers outside academia. From the CNRS example, Brischoux and Angelier (2015) also showed that the time elapsed between first publication and recruitment had increased from 3.25 to 8 years. The increase in postdoctoral training time can be detrimental to not only the scientific community but also individuals because this increases the age at which researchers become independent, during which the postdocs have to trade off families for research, with fixed-term and relatively low-paying jobs [10].

Despite widely claimed that publication expectations and career duration have surged, empirical quantification of the determinants regarding the evolution of academic profiles over time remains understudied. In addition to research productivity, which directly predicts the success of recruitment [11], the origin and prestige of doctoral-granting institutes have become critical indicators for academic employment [11], especially in East Asian countries [12]. With the initiative to build world-class universities, many East Asian universities preferentially recruit returnees who obtained PhD degrees from top-ranking universities in Western countries. Hence, competition for limited tenure-track positions is exacerbated when foreign PhDs are favored, leaving domestically-trained PhDs substantially deprived of career development opportunities [13]. Yet, whether and to what extent publication expectations and career duration differ between domestic and foreign PhDs, and if their academic productivity varies between pre- and post-employment, remain largely unexplored.

In this study, we examined how academic performance as well as the duration for landing tenure-track positions and promotion to full professor changed over time, and their links to PhD university origin, PhD university ranking, and gender. Specifically, we tested the following questions: (1) Is the academic performance for recruitment as a new principal investigator (PI) or promotion to full professor affected by the year of recruitment, PhD university origin, ranking, and gender? (2) Is the duration for recruitment or promotion affected by the year of recruitment, academic performance, PhD university origin, ranking, and gender? (3) Does the academic performance of PIs differ before and after recruitment or promotion? To address these questions, we studied the trend between 1987 and 2021 on 140 faculty members in the field of ecology and evolutionary biology in Taiwan. We aim to provide empirical evidence to illustrate the temporal variations in researchers' publication performance necessary to secure a faculty position and get a promotion, the role of PhD university origin and prestige as well as gender in determining the success of academic employment, and how these factors contribute to PIs' future academic performance.

Materials and Methods:

(a) Data collection

Between November and December, 2021, we surveyed tenure-track faculty members at seven universities in Taiwan, all of which were qualified as research-intensive universities and ranked top 150 in Asia according to 2022 QS Asia University Rankings (https://www.topuniversities.com/). We also surveyed academics from Academia Sinica, a leading academic institution in Taiwan. Together, these eight institutes encompassed 34 academic departments/divisions that serve as tenure homes to the field of ecology and evolutionary biology (e.g., ecology, evolution, biodiversity; see Appendix A for details). We excluded researchers in biomedical sciences because publication rates, performance, and collaboration opportunities can vary considerably among these fields [14]. A total of 140 PIs who had an updated curriculum vitae online (e.g., institutional/personal websites or Open Researcher and Contributor ID [ORCID]) were identified in our survey, with key information on the university and year of PhD completion, the year of recruitment as a new PI, the year of promotion to full professor, and gender, which is well-documented as a key determinant of performance [15]. The university ranking

was determined based on 2022 QS World University Rankings. The duration for recruitment as a new PI was the time between PhD completion and landing a position; the duration for promotion to full professor was the time between landing a position and getting a promotion.

(b) Measurement of academic performance

We collected data on academic performance, measured as h-index [16], from the Publish or Perish software using Google Scholar data, which is freely available and more transparent for tenure reviews [17]. We included peer-reviewed papers and book chapters regardless of authorship for calculation of h-index, while PhD theses and conference presentations were excluded. Although other matrices, such as the number of publications and citations, are also commonly used for measuring academic performance, they were both highly correlated with h-index in our study (publications: $r = 0.906$, $p < 0.001$; citations: $r = 0.768$, $p < 0.001$), as had also been found in previous studies [14,18]. We thus focused on h-index, a widely accepted measure of academic success that incorporates the assessment of quantity (number of papers) and quality (citations) of publications [19].

We calculated h-index within the five-year interval both before and after the year of recruitment and promotion, generating up to four h-indexes for each PI. We used the duration of five years because it is commonly used by institutes to evaluate the most recent academic performance both for recruiting a new PI and for promotion to full professor. The publications and citations during the year of recruitment and promotion were considered as the performance “before” getting a job and promotion to full professor because these publications, either as published papers or manuscripts “accepted” or “in press”, would most likely contribute to the evaluation of academic performance prior to successful recruitment and promotion. For example, a new PI who started the position in 2010 would have an h-index measured for publications between 2006 and 2010 (i.e., “before” h-index), and another h-index measured for publications between 2011 and 2015 (i.e., “after” h-index). We did not consider “after” h-indexes for PIs who were recruited as a new PI or promoted to full professor less than five years so that all performances had the same duration to compare with.

(c) Statistical analysis

Academic performance before recruitment/promotion. To examine how various factors affect the academic performance before recruitment as a new PI and promotion to full professor, we fit generalized linear mixed-effects models (GLMMs) with PhD university origin (binary variable: Taiwan vs. Foreign), PhD university ranking, year of recruitment/promotion, gender, and interactions with year as fixed effects, the department nested within university as random effects, and the h-index before recruitment/promotion as the response.

Duration for recruitment/promotion. To examine how various factors affect the duration for recruitment and promotion, we fit GLMMs with PhD university origin, PhD university ranking, year of recruitment/promotion, gender, the h-index before recruitment/promotion, and interactions with year as fixed effects, the department

nested within university as random effects, and the duration for recruitment/promotion as the response.

Changes in academic performance before and after recruitment/promotion. To compare the academic performance before and after recruitment and promotion, we fit GLMMs with PhD university origin, PhD university ranking, year of recruitment/promotion, gender, and interactions with year as fixed effects, the department nested within university as random effects, and the difference in h-index before and after recruitment/promotion (i.e., "after" h-index – "before" h-index) as the response.

GLMMs were performed using the package "lme4" [21]; post-hoc pairwise comparisons were performed using the package "emmeans" [22]. Response variables (h-index and duration for recruitment/promotion) were log-transformed prior to analyses to meet the assumption of normality. The assumption of independence and equal variance were both assessed using the residual plots. Non-significant interactions ($p > 0.05$) were dropped from our final model results. All analyses were performed in R version 4.1.2 [20].

Results:

In total, we collected data on140 tenure-track faculty members, of which 43.6% were full professors, 25.0% were associate professors, and 31.4% were assistant professors. The gender difference was substantial, with males (109) four times as prevalent as females (31). The universities from which the PIs obtained their PhD degrees varied widely in the ranking of prestige among 73 universities from 16 countries (Fig. S1 and S2). Nearly half of the PIs obtained their degrees from the USA (47%), followed by Taiwan (31%), and relatively few from the UK (5%) and other countries.

Faculty members who landed tenure-track positions more recently had higher academic performance (h-index) before recruitment, whereas PIs performed equally well before promotion to full professor irrespective of time (Table 1; Fig. 1a and b). Although males had on average higher performance than females before recruitment, no such gender difference was found before promotion. PhD university origin and ranking had no effect on the performance either before recruitment or before promotion (Table 1).

Faculty members who landed positions more recently spent more time post-PhD before recruitment, but higher academic performance reduced this duration (Table 1; Fig. 1c). On the other hand, PIs also spent more time before promotion to full professor in recent years, yet the duration was not affected by the academic performance (Table 1; Fig. 1d). PhD university origin, ranking, and gender had no effect on the duration for either recruitment or promotion (Table 1).

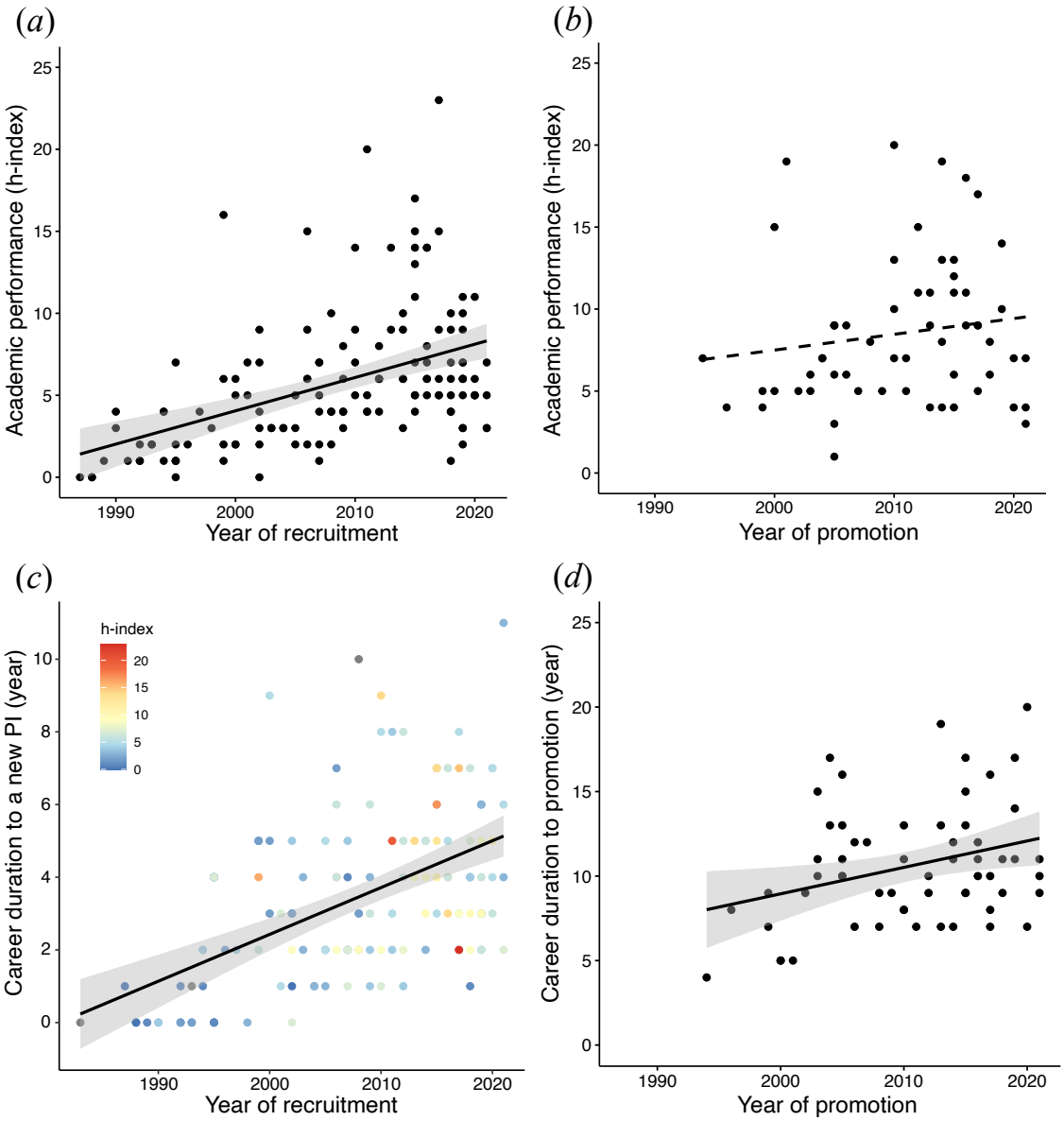

Fig. 1. Temporal variations in academic performance (*a* & *b*) and career duration (*c* & *d*) for recruitment and promotion. Each point represents an individual PI, with points in (*c*) colored by h-index. Solid/dashed lines represent significant/non-significant relationships predicted from GLMMs; shaded areas indicate 95% confidence intervals.

The difference in academic performance before and after recruitment ("after" h-index – "before" h-index) decreased for PIs who landed positions more recently, while PhD university origin, ranking, and gender had no effect on the performance difference (Table 1; Fig. 2a and b). In contrast, the performance difference before and after promotion to full professor was not affected by the year of promotion, PhD university ranking, or gender, yet the difference tended to be higher for PIs with foreign degrees compared to those with Taiwanese degrees (Table 1; Fig. 2c and d).

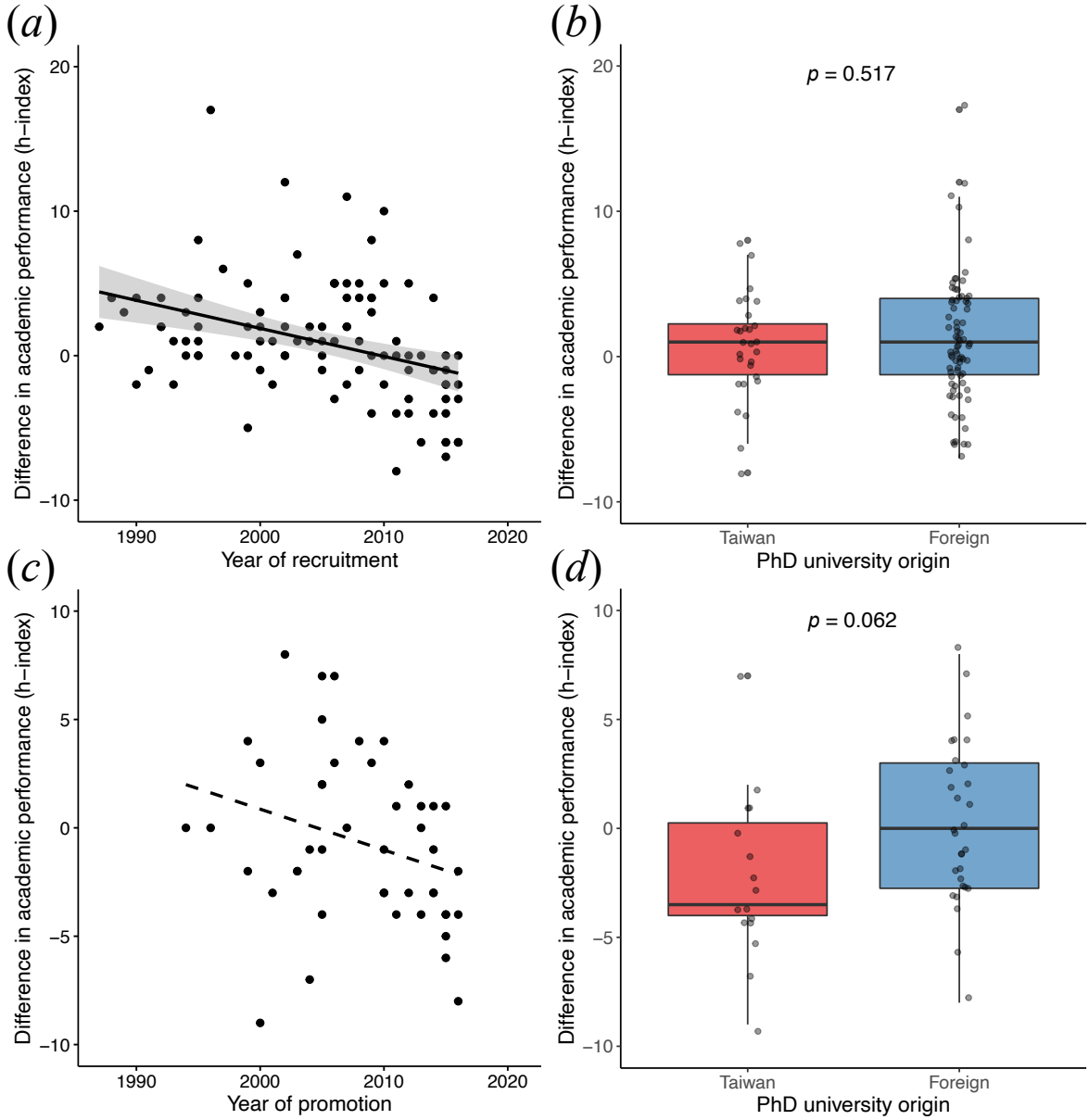

Fig. 2. Difference in academic performance before and after ("after" h-index – "before" h-index) recruitment as a new PI (*a & b*) and promotion to full professor (*c & d*) in relation to year of recruitment/promotion and PhD university origin. Each point represents an individual PI. Solid/dashed line represents significant/non-significant relationship predicted from GLMMs; shaded areas indicate 95% confidence intervals.

Discussion:

Overall, we showed that the academic performance of PIs before landing faculty positions increased over years, whereas the performance before promotion to full professor remained relatively unchanged. We also found that the duration for both recruitment and promotion increased in recent years. These results provide empirical evidence supporting the suspicion that publication requirements and expectations

have risen over time in ecology and evolution in Taiwan, in line with many academic job markets worldwide [23,24].

The increase in academic performance of PIs before recruitment suggests that the academic job market has become increasingly competitive over time, which is likely driven by a relatively lower demand for tenure-track professors compared to the supply of new PhDs [5]. Consequently, the duration post-PhD would be prolonged if the applicants are not competitive enough. However, higher academic performance could help shorten the time to land a position. Therefore, early-career researchers should focus on their publications to demonstrate the competence for academic success. On the other hand, the academic performance of PIs before promotion remained similar over years, suggesting that the requirements for promotion might not have changed much over time. Interestingly, the time to full professor has lengthened in recent years but was not affected by academic performance, possibly due to increasing consideration of accomplishments such as teaching and administrative services by employment institutes in addition to research outputs. The different patterns in academic performance and career duration between recruitment and promotion phase are likely because applicants face increasing competition with others during recruitment and higher performance would be advantageous for securing a position, whereas getting a promotion depends mainly on meeting the institutes' requirements rather than comparing with others' performance.

We found that the average performance of a new male PI was higher than that of a new female PI, indicating that the standards for evaluating the suitability of a potential faculty member might be higher for males than females [25]. But after recruitment, the performance expectations for promotion to full professor did not differ between male and female PIs. In contrast to a previous study [11], we found no evidence of PhD university origin and ranking influencing the career duration for either recruitment or promotion. Instead, academic performance during PhD and/or post-PhD period is more important in determining the academic success compared with the prestige of education itself.

The difference in performance before and after recruitment decreased over years. Earlier PIs had on average higher h-indexes after recruitment compared with before recruitment, yet such a "performance boost" has declined in recent years. This could be due to increasing teaching and administrative demands of new PIs, reducing the time available for research. Strikingly, we found that PIs performed consistently before and after recruitment regardless of PhD university origin or ranking. However, PIs with PhD degrees in Taiwan showed a decrease in performance after promotion to full professor, whereas those with foreign PhD degrees had relatively consistent performance. One possible explanation is that the training and experiences from foreign universities may have equipped those PIs with greater professional abilities, which together with international connections and collaboration opportunities, helps maintain their performance.

Our findings were based mainly on PIs in ecology and evolutionary biology. Since the nature of academic job markets can vary considerably among different fields of biology [5], the results should be interpreted carefully when applied to the fields

outside the scope of this study. Nonetheless, our findings confirm that succeeding in academia has become more challenging, with publication requirements and career duration both increasing over time. In the face of increasingly competitive academic job markets, boosting performance is the key to career success in academia.

Authors' contributions:
G.-C.H. and S.-J.S. conceived the study; W.-J.L. and S.-J.S. collected the data; G.-C.H. and S.-J.S. analyzed the data. All authors were involved in writing the manuscript.

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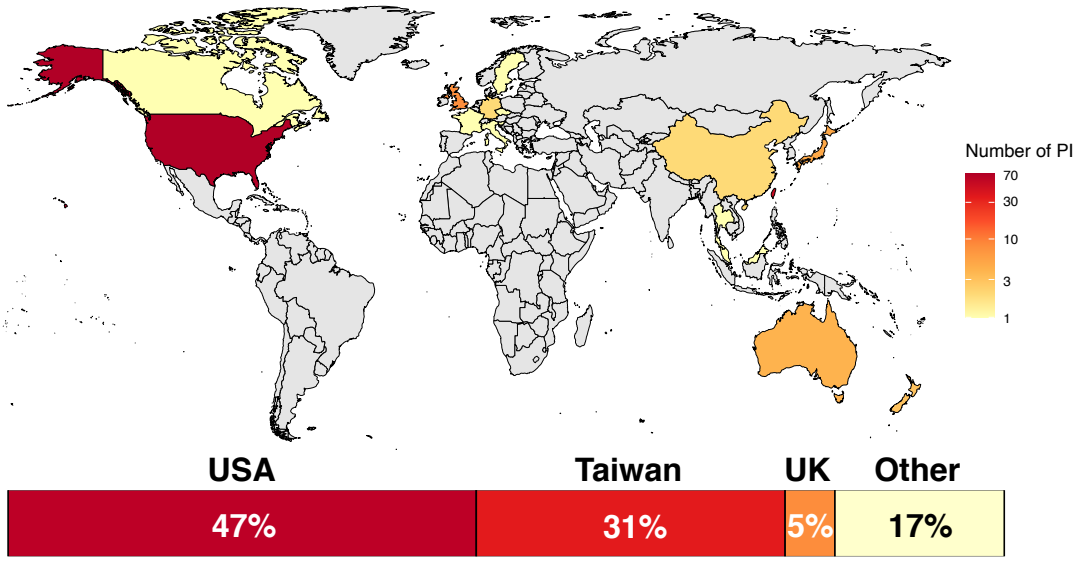
385 **Supplementary information:**



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387 Fig. S1. Distribution of the universities from which the 140 PIs obtained their PhD
388 degrees. Percentages of PhD degrees obtained from the USA, Taiwan, and the UK
389 are as noted, whereas “other” includes those less than 3%.
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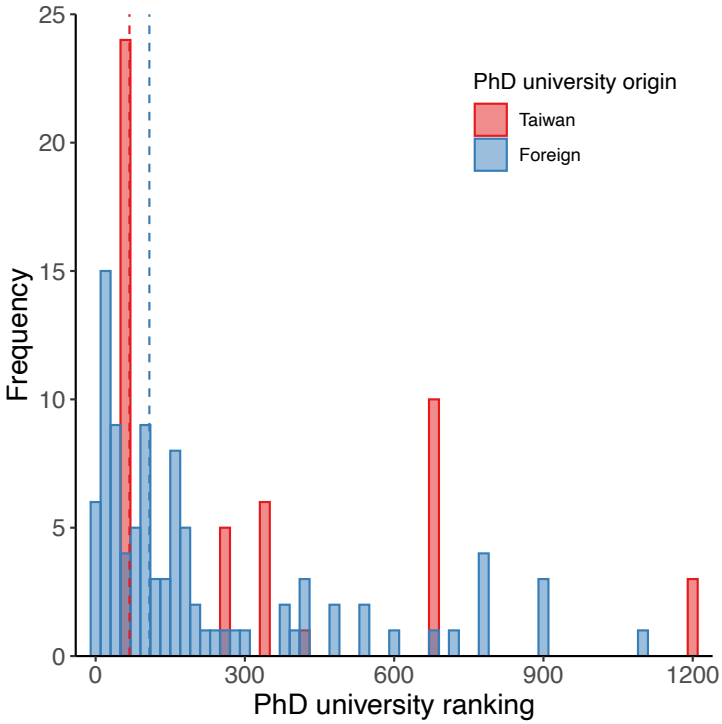

Fig. S2. Distribution of the ranking of universities from which PIs obtained their PhD degrees. Dashed lines indicate medians of university ranking for Taiwanese (68) and foreign (108) PhD degrees.

Table 1. Results of the GLMMs for analyzing academic performance, career duration, and difference in performance before and after recruitment as a new PI and promotion to full professor.

Response	Predictor	χ^2	d.f.	*p*
Academic performance (new PI)	PhD university origin	1.42	1	0.234
	PhD university ranking	0.45	1	0.503
	Year of recruitment	74.68	1	**<0.001**
	Gender	5.73	1	**0.017**
Academic performance (promotion)	PhD university origin	0.06	1	0.812
	PhD university ranking	1.06	1	0.304
	Year of promotion	0.97	1	0.324
	Gender	0.07	1	0.791
Duration (new PI)	Academic performance	5.47	1	**0.019**
	PhD university origin	1.01	1	0.315
	PhD university ranking	1.82	1	0.178
	Year of recruitment	43.08	1	**<0.001**
	Gender	0.78	1	0.377
	Academic performance x Year of recruitment	6.06	1	**0.014**
Duration (promotion)	Academic performance	1.87	1	0.171
	PhD university origin	1.96	1	0.161
	PhD university ranking	0.62	1	0.430
	Year of promotion	7.03	1	**0.008**
	Gender	3.18	1	0.075
Difference in performance (new PI)	PhD university origin	0.42	1	0.517
	PhD university ranking	0.38	1	0.537
	Year of recruitment	15.40	1	**<0.001**
	Gender	0.06	1	0.800
Difference in performance (promotion)	PhD university origin	3.48	1	0.062
	PhD university ranking	0.51	1	0.474
	Year of promotion	2.96	1	0.086
	Gender	0.81	1	0.369

p values < 0.05 are highlighted in bold

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