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Temporal trends in academic performance and career duration of principal investigators in ecology and evolutionary biology in Taiwan

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Abstract:	Academic job markets have become increasingly challenging worldwide, with rising performance requirements for recruitment as a new faculty member and promotion to full professor in recent years. However, it remains underexplored how research performance and other determinants of academic success, including PhD university origin, prestige, and gender, affect recruitment and promotion over time. Focusing on the field of ecology and evolutionary biology in Taiwan, we analyzed the academic performance (measured as h-index) as well as the duration before recruitment and promotion of 145 principal investigators (PIs) over the past 34 years. We found that the performance of PIs before recruitment and before promotion both increased in recent years, and male PIs had on average higher performance than female PIs before recruitment. Moreover, the career duration before recruitment and before promotion both increased in recent years. PIs with Taiwanese PhD degrees tended to have longer duration before recruitment. PhD university ranking had no effect on performance and duration either before recruitment or before promotion. We also found that academic performance of PIs recruited in recent years decreased post-recruitment. Furthermore, PIs with Taiwanese PhD degrees appeared to exhibit a drop in performance post-promotion compared to those with foreign degrees. Taken together, our study reveals increased academic performance requirements and career duration of PIs in ecology and evolutionary biology in Taiwan over the last three decades, and illustrates the role of PhD degree and gender in determining academic

	success.
Response to Reviewers:	Response to Reviewers' Comments Date: March 28, 2023 Manuscript Number: SCIM-D-22-00945R3 Title of Article: Temporal trends in academic performance and career duration of principal investigators in ecology and evolutionary biology in Taiwan Corresponding Author: Syuan-Jyun Sun (sjs243@ntu.edu.tw) ---------- Dear Dr. Lin Zhang, Thank you for inviting us to submit a revised version of the manuscript. We greatly appreciate the valuable comments and feedback from the reviewers and have incorporated the suggestions in the revision. In particular, we have made the following major changes: •Re-ran the entire analyses with book/book chapters excluded from the calculation of h-index and updated the methods, results, table, and figures accordingly. •Added a paragraph in the methods section discussing the representativeness of the PIs in our analyses. Please see the following section for our detailed point-by-point responses. All line numbers pertaining to the changes refer to the revised manuscript. Sincerely, Syuan-Jyun Sun (corresponding author) on behalf of Gen-Chang Hsu and Wei-Jiun Lin ---------- Reviewer 2's Comments to the Author(s): The authors have responded to most of my concerns. However, there are still two issues that i believe the authors should address before I can recommend accept. Comment 1 > Regarding the authors response to Comment 6: The authors answer: "Regarding the citation practices of journal articles and books/book chapters, we agree that these two publication types may have different citation patterns, but our main point is that both of them are critical research performance and contribute substantially to the evaluation of PIs' job application and promotion. In this regard, we included both journal articles and books/book chapters in the calculation of h-index." Yes, but different publication types are generally not comparable and the evidence for this is very strong in the scientometric literature. This is problematic since it means that the authors might compare authors that mostly publish in articles with authors that mostly publish in books/shapters which is like comparing apples with oranges. My recommendation is that the authors construct a proper performance measure in accordance with best practice in the scientometric literature. For example, constructing an indicator that takes this issue into consideration. Or, Exclude books/chapters and see if the results differ from the results when both document types are included. Or some other solution that show either that their indicator is not biased as the scientometric literature would suggest, or make adjustment for the potential bias with good arguments for why their solution works. Response > Thanks for the suggestions. To address the issue regarding the differences in citation patterns among different types of publications, we have decided to exclude the book/book chapters from the calculation of h-index as there were not many such publications in our original data (see the attachment "Number_of_books_excluded.xlsx" for the number of book/book chapters excluded for each PI) and re-run all the analyses (Line 194-198): "After the search was completed, we checked individually each publication item in the results pane and included only peer-reviewed journal articles; PhD theses, conference presentations, and book/book chapters were excluded from the calculation of citation metrics as their citation patterns may differ from that of journal articles." The statistical results, table, and figures were updated accordingly. The new data set has also been uploaded to the manuscript submission system as a supplementary file. We also compared the model outputs from previous vs. new analyses to check whether excluding book/book chapters altered the results. Despite some minor changes in the actual numbers, the overall conclusions from both analyses were the same. ModelPredictorBook/book chapters included

(original)Book/book chapters excluded
(new)
βSEPβSEP
Model 1.
Academic performance (recruitment)Year of recruitment0.04290.0004< 0.0010.04310.0004< 0.001
PhD university origin (Taiwan)-0.06060.10970.855-0.06960.10940.855
PhD university ranking0.00010.00020.7220.00010.00020.721
Gender (Male)0.45100.1326< 0.0010.45900.1314< 0.001
Model 2.
Academic performance (promotion)Year of promotion0.00480.0007< 0.0010.01050.0007< 0.001
PhD university origin (Taiwan)-0.15940.11380.161-0.17210.11190.124
PhD university ranking0.00010.00020.979-0.00010.00020.977
Gender (Male)-0.05840.13650.669-0.15590.13180.237
Model 3.
Career duration (recruitment)“Before” h-index (recruitment)0.01930.01340.1490.01760.01350.191
Year of recruitment0.03770.0064< 0.0010.03690.0063< 0.001
PhD university origin (Taiwan)0.17590.10090.0810.19140.10040.057
PhD university ranking-0.00030.00020.137-0.00020.00020.190
Gender (Male)-0.07440.11980.535-0.09970.11790.398
Model 4.
Career duration (promotion)“Before” h-index (promotion)-0.01050.01090.338-0.01760.01060.096
Year of promotion0.01450.00640.0240.01240.00640.053
PhD university origin (Taiwan)0.12480.09450.1870.08440.09570.378
PhD university ranking-0.00020.00010.256-0.00020.00020.249
Gender (Male)-0.16170.10640.129-0.10520.10540.318
Model 5.
Difference in performance (recruitment)Year of recruitment-0.18660.0476< 0.001-0.18070.0492< 0.001
PhD university origin (Taiwan)-0.57120.88090.517-0.17840.90590.844
PhD university ranking0.00090.00150.5370.00110.00150.456
Gender (Male)0.24870.98370.800-0.10470.99490.916
Model 6.
Difference in performance (promotion)Year of promotion-0.16710.09720.086-0.16140.09850.101
PhD university origin (Taiwan)-2.15771.15610.062-2.04581.20240.089
PhD university ranking0.00130.00180.4740.00170.00190.362
Gender (Male)1.18351.31680.3690.71201.35450.599

Comment 2 > Regarding the authors’ response to Comment 6: My recommendation is that the authors include the assessment of representativity (i.e., descriptive statistics, the population, and the chi2 test) in the manuscript so that this information is available for the readers.
Response > We have now included this information in the methods section (Line 171-184):
“We focused on PIs at the eight top-ranked universities/institution rather than PIs at all universities in Taiwan because the research environment and funding resources can differ substantially among universities, and such differences could potentially affect the research outputs of PIs and thus bias the results. However, to ensure that the 145 PIs in our analyses are representative of the entire PI pool, we conducted a further survey following the same criteria and identified additional 81 PIs in the field of ecology and evolutionary biology (yielding a total of 226 PIs as the “population” underlying our study), and compared the academic rank (assistant professor, associate professor, and full professor) and gender composition (male and female) of our PI samples against those of the entire PI population. The results of goodness of fit test showed that the academic rank and gender composition of our PI samples did not deviate from those of the entire PI population (academic rank: $\chi 2 = 1.26$, df = 2, P = 0.53; gender: $\chi 2 = 0.64$, df = 1, P = 0.42), confirming the representativeness of the PIs in our study.”

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Temporal trends in academic performance and career duration of principal investigators in ecology and evolutionary biology in Taiwan

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Abstract

Academic job markets have become increasingly challenging worldwide, with rising performance requirements for recruitment as a new faculty member and promotion to full professor in recent years. However, it remains underexplored how research performance and other determinants of academic success, including PhD university origin, prestige, and gender, affect recruitment and promotion over time. Focusing on the field of ecology and evolutionary biology in Taiwan, we analyzed the academic performance (measured as h-index) as well as the duration before recruitment and promotion of 145 principal investigators (PIs) over the past 34 years. We found that the performance of PIs before recruitment and before promotion both increased in recent years, and male PIs had on average higher performance than female PIs before recruitment. Moreover, the career duration before recruitment and before promotion both increased in recent years. PIs with Taiwanese PhD degrees tended to have longer duration before recruitment. PhD university ranking had no effect on performance and duration either before recruitment or before promotion. We also found that academic performance of PIs recruited in recent years decreased post-recruitment. Furthermore, PIs with Taiwanese PhD degrees appeared to exhibit a drop in performance post-promotion compared to those with foreign degrees. Taken together, our study reveals increased academic performance requirements and career duration of PIs in ecology and evolutionary biology in Taiwan over the last three decades, and illustrates the role of PhD degree and gender in determining academic success.

Keywords

academic job market, academic performance, career duration, h-index, PhD degree, principal investigator, publication

Introduction

The academic job market has been increasingly competitive in many fields of science, technology, engineering, and mathematics (STEM) (Cyranoski et al. 2011; Ghaffarzadegan et al. 2015; Xue and Larson 2015), with more PhDs produced but vacancies for tenure-track academic positions remaining relatively constant over the past four decades (Larson et al. 2014; Schillebeeckx et al. 2013). For example, in the US, only 7.6% of new PhDs in life sciences landed tenure-track positions within three years after graduation in 2010. Such a surplus of PhD supply has also emerged in other STEM fields (National Science Foundation 2018).

The intensified competition for tenure-track positions, due to disproportionately high numbers of applicants per position (Larson et al. 2014), has resulted in higher expectations for academic performance shaped by a *"publish or perish"* culture (Garfield 1996). 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 (Brischoux and Angelier 2015). Furthermore, 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 PhDs in STEM work as postdoctoral researchers for a prolonged period of time and wait for future opportunities until they are competitive enough in the academic job markets (Swihart et al. 2016), whereas some turn to alternative careers outside academia. In the aforementioned CNRS example, Brischoux and Angelier (2015) also found that the time between first publication and recruitment had increased from 3.25 to 8.0 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, and they have to trade off families for research, with fixed-term and relatively low-paying jobs (Acton et al. 2019).

As the number of applicants largely surpasses the available faculty positions, understanding what factors contribute to a researcher's success in the increasingly competitive academic job market has become the center of attention. Among the determinants of academic excellence and career success, research performance is arguably the most critical one (Danell 2011, Acuna et al. 2012, van Dijk et al. 2014). Researchers with more publications, in particular highly cited and top journal publications, tend to be more successful in their long-term careers (Lindahl 2018, Hou et al. 2022). Moreover, researchers having more first author publications and publishing more in top journals have higher h-indexes and are more likely to become principal investigators (PIs) (van Dijk et al. 2014). Research performance is crucial for academic success as publication requirements for recruitment as a new faculty member and promotion to full professor have surged in recent years. Yet, empirical quantification of how research performance affects researchers' career duration for recruitment and promotion over time remains unexplored.

In addition to research performance, the prestige of doctoral-granting institutions can influence academic employment as well (van Dijk et al. 2014). Higher doctoral prestige is associated with increased rates of recruitment success and better faculty placement (Clauset et al. 2015). In East Asian countries, the initiative to build world-class universities has led many universities to preferentially recruit returnees who

obtained PhD degrees from top-ranked universities in Western countries (Shin and Kehm 2013). Hence, competition for limited tenure-track positions is exacerbated when foreign PhDs are favored, leaving domestically-trained PhDs deprived of career development opportunities (Chen 2021). However, whether and to what extent publication performance and career duration differ between researchers with domestic and foreign degrees, and whether their pre- and post-employment performance changes, remain largely unclear.

Gender is another determinant of research performance and career success across STEM fields (Larivière et al. 2013, Huang et al. 2020). For example, studies have shown that male researchers have higher publication rates, receive more citations, and make greater scientific impacts compared to their female counterparts (Symonds et al. 2006, West et al. 2013, McDermott et al. 2018, but see Huang et al. 2020). Moreover, males have a higher probability of becoming PIs (van Dijk et al. 2014) and often land positions at higher-ranked institutions than females (Clauset et al. 2015). Yet, despite the well-documented gender gaps in research outputs and academic job market success, little is known about the gender differences in career duration, that is, whether the time to land a faculty position and to get a promotion differs between male and female researchers.

To address these gaps, we investigated how academic performance as well as duration before recruitment as a new faculty member and promotion to full professor changed over time, and how PhD university origin, PhD university ranking, and gender affected the career success of PIs, in the field of ecology and evolutionary biology in Taiwan. Specifically, we examined the following questions: (1) Is the

academic performance of PIs before recruitment/promotion associated with the year of recruitment/promotion, PhD university origin, ranking, and gender? (2) Is the duration before recruitment/promotion associated with the year of recruitment/promotion, academic performance, PhD university origin, ranking, and gender? (3) Do the year of recruitment/promotion, PhD university origin, ranking, and gender affect the difference in academic performance before and after recruitment/promotion? We aim to provide empirical evidence illustrating the temporal trends in researchers' publication performance and the time required to land a faculty position or get a promotion, as well as to explore the role of PhD degree and gender in determining the success of academic employment and promotion.

Materials and Methods

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. We defined the field of ecology and evolutionary biology based on the scope of the journal *Ecology and Evolution* (https://onlinelibrary.wiley.com/journal/20457758), which encompasses research on micro- and macro-evolutionary processes, individual physiological responses to the environment, population genetics and phylogenetics, systematics and taxonomy, organisms behavior, species abundance and distribution, species interactions, community and ecosystem dynamics, and biodiversity and conservation.

To identify the PIs for our analyses, we first generated a list of biology-related departments/divisions at the eight top-ranked universities/institution in Taiwan, which consisted of a total of 81 departments/divisions. We then excluded those departments/divisions that focus primarily on biomedical sciences, leaving 33 departments/divisions after this filtering. For these 33 departments/divisions, we visited the websites and recorded PIs whose areas of research and publications fell within our definition of ecology and evolutionary biology. A total of 145 PIs with an updated curriculum vitae online (e.g., institutional/personal websites or Open Researcher and Contributor ID [ORCID]) were identified in our survey. For each PI, we recorded information on the university and year of PhD completion, year of

recruitment as a new PI, year of promotion to full professor (only for PIs who were full professors), and gender. The rankings of PhD universities were determined based on 2022 QS World University Rankings. The duration before recruitment as a new PI was calculated as the time between PhD completion and landing a faculty position; the duration before promotion to full professor was calculated as the time between landing a position and getting a promotion.

We focused on PIs at the eight top-ranked universities/institution rather than PIs at all universities in Taiwan because the research environment and funding resources can differ substantially among universities, and such differences could potentially affect the research outputs of PIs and thus bias the results. However, to ensure that the 145 PIs in our analyses are representative of the entire PI pool, we conducted a further survey following the same criteria and identified additional 81 PIs in the field of ecology and evolutionary biology (yielding a total of 226 PIs as the "population" underlying our study), and compared the academic rank (assistant professor, associate professor, and full professor) and gender composition (male and female) of our PI samples against those of the entire PI population. The results of goodness of fit test showed that the academic rank and gender composition of our PI samples did not deviate from those of the entire PI population (academic rank: $\chi^2 = 1.26$, $df = 2$, $P = 0.53$; gender: $\chi^2 = 0.64$, $df = 1$, $P = 0.42$), confirming the representativeness of the PIs in our study.

We collected citation data of PIs via the *Publish or Perish* software, which uses Google Scholar Profiles queries to obtain citation information of researchers' publications and converts it into several citation metrics (e.g., total number of

citations, citations per year, and h-index). The data collection was conducted at the individual level by entering each PI's full name or the abbreviated version in scientific publications to the search field. The range of years was set based on the year of recruitment and promotion for each PI (five-year interval before and after the year of recruitment/promotion; see the following section *Measurement of academic performance* for more details). After the search was completed, we checked individually each publication item in the results pane and included only peer-reviewed journal articles; PhD theses, conference presentations, and book/book chapters were excluded from the calculation of citation metrics as their citation patterns may differ from that of journal articles. Duplicate items were removed from the search results. The final citation metrics were then exported for further statistical analyses.

We performed citation searches via Google Scholar Profiles because it is freely available and thus more transparent for tenure reviews (Pauly and Stergiou 2005). Moreover, its high coverage allows researchers to obtain comprehensive bibliometric data (Martín-Martín et al. 2021). A major limitation of Google Scholar Profiles is that the metadata for publications (e.g., publication type, DOI, and funding information) are relatively limited compared to other search engines such as Web of Science or Scopus (Martín-Martín et al. 2018) (also see Martín-Martín et al. [2018] for detailed comparisons of the strengths and weaknesses of various academic search engines for bibliometric analyses). This limitation is not a major concern for our study because we did not use such metadata in our analyses.

Measurement of academic performance

We used h-index as a measurement of academic performance (Hirsch 2005), a widely accepted metric that incorporates the assessment of publication quantity (number of publications) and quality (number of citations) (Glänzel 2006). The number of publications and citations were both highly correlated with h-index in our study (number of publications: $r = 0.91$, $P < 0.001$; number of citations: $r = 0.77$, $P < 0.001$) (such high correlations have also been reported in previous studies, e.g., Laurance et al. [2013] and Ryan Haley [2012]). Furthermore, h-index is robust to a few highly-cited or a set of lowly-cited publications, rending it suitable for evaluating the overall impact of a researcher's outputs (Bornmann and Daniel 2007). Although h-index can vary considerably among different fields of study (Alonso et al. 2009), we focused on PIs within the field of ecology and evolutionary biology and thus their h-indexes should be fairly comparable.

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 (some PIs had only one to three such h-indexes depending on their career stages at the time when the data were collected). We used the duration of five years because this time span is commonly used by institutions 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 recruitment and promotion 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 PI who started a position in 2010 would have an h-index measured for publications between 2006 and 2010 (i.e.,

"Before" h-index for recruitment), and another h-index measured for publications between 2011 and 2015 (i.e., "After" h-index for recruitment). We did not compute "After" h-index for PIs who were recruited or promoted less than five years (as of 2022) so that the h-indexes for all PIs in our analyses were comparable.

Statistical analyses

(1) Academic performance before recruitment/promotion (Model 1 and 2). 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 models (GLMMs) (Bolker et al. 2009) with the "Before" h-index for recruitment/promotion as the response, year of recruitment/promotion, PhD university origin (Taiwan vs. Foreign), PhD university ranking, and gender (Male vs. Female) as fixed effects, and the department/division nested within university as random effects. Model 1 was fitted with a negative binomial error distribution and a log link function as the response was non-negative integers with significant overdispersion (χ^2 = 198.7, *df* = 127, $P < 0.001$); Model 2 was fitted with a Poisson error distribution and a log link function as no significant overdispersion was detected (χ^2 = 70.3, *df* = 52, $P = 0.05$).

(2) Duration before recruitment/promotion (Model 3 and 4). To examine how various factors affect the duration before recruitment and promotion, we fit GLMMs with the duration before recruitment/promotion as the response, the "Before" h-index for recruitment/promotion, year of recruitment/promotion, PhD university origin (Taiwan vs. Foreign), PhD university ranking, and gender (Male vs. Female) as fixed effects, and department/division nested within university as random effects. Both Model 3 and 4 were fitted with a Poisson error distribution and a log link function as the

response was non-negative integers without significant overdispersion (Model 3: χ^2 = 149.8, *df* = 126, *P* = 0.07; Model 4: χ^2 = 31.9, *df* = 49, *P* = 0.97).

(3) Difference in academic performance before and after recruitment/promotion (Model 5 and 6). To examine how various factors affect the difference in academic performance before and after recruitment/promotion, we fit linear mixed-effects models (LMMs) (Bolker et al. 2009) with the difference between "After" and "Before" h-index for recruitment/promotion ("After" h-index minus "Before" h-index) as the response, year of recruitment/promotion, PhD university origin (Taiwan vs. Foreign), PhD university ranking, and gender (Male vs. Female) as fixed effects, and the department/division nested within university as random effects. The LMMs were fitted with a Gaussian error distribution and an identity link function.

A total of six models (four GLMMs and two LMMs) were performed using the glmer()/lmer() function in the R "lme4" package (Bates et al. 2015). Only full observations were used in each model (observations with any missing entry were omitted; see Table 1 for the actual sample size for each model). The assumptions of equal variance and normality were assessed using residual plots and QQ-plots. Significance ($\alpha = 0.05$) of model coefficients was tested (Wald chi-square test with type II sum of squares) using the Anova() function in the R "car" package (Fox and Weisberg 2019). All analyses were performed in R version 4.2.2 (R Development Core Team 2022).

Results

Our final data included a total of 145 tenure-track faculty members recruited between 1987 and 2021, of which 44.8% were full professors, 24.8% were associate professors, and 30.3% were assistant professors. Nearly half of the PIs obtained their PhD degrees from the USA (45.5%), followed by Taiwan (33.1%), and relatively few from the UK (4.8%) and other countries (Fig. 1). The PhD universities varied widely in the ranking of prestige among 73 universities from 17 countries (Fig. 2). The gender difference was substantial, with males (112) being more than three times as many as females (33).

Academic performance before recruitment/promotion

The academic performance before recruitment ("Before" h-index for recruitment) was higher for PIs who landed tenure-track positions more recently (Model 1; Table 1, Fig. 3a). Similarly, the performance before promotion to full professor ("Before" h-index for promotion) was higher for PIs who got promoted more recently (Model 2; Table 1, Fig. 3b), though the rate of increase was lower compared to that before recruitment (β for recruitment vs. promotion: 0.043 vs. 0.011; Table 1). Male PIs had on average higher performance than female PIs before recruitment, while no such gender difference was found before promotion (Model 1 and 2; Table 1). PhD university origin and ranking had no significant effect on the performance either before recruitment or before promotion (Model 1 and 2; Table 1).

Duration before recruitment/promotion

PIs who landed positions more recently spent more time post-PhD before recruitment (Fig. 3c). PIs with Taiwanese PhD degrees tended to have longer

durations before recruitment (Model 3; Table 1). PIs also spent more time before promotion to full professor in recent years (Fig. 3d), yet the duration was not related to the PhD university origin (Model 4; Table 1). Academic performance, PhD university ranking, and gender had no significant effect on the duration either before recruitment or before promotion (Model 3 and 4; Table 1).

Difference in academic performance before and after recruitment/promotion

The difference in academic performance before and after recruitment ("After" h-index minus "Before" h-index) decreased for PIs who landed positions more recently (Fig. 4a); PhD university origin, ranking, and gender had no effect on the performance difference before and after recruitment (Model 5; Table 1, Fig. 4b). The difference in performance before and after promotion to full professor also decreased over years, although not statistically significant (Fig 4c). Moreover, the performance difference before and after promotion tended to be higher for PIs with foreign degrees compared to those with Taiwanese degrees (Fig. 4d). PhD university ranking and gender had no significant effect on the performance difference before and after promotion (Model 6; Table 1, Fig. 4d).

Discussion

Overall, we found that the academic performance of PIs before recruitment as new faculty members as well as before promotion to full professors both increased over years. We also showed that the career duration before recruitment and before promotion both increased in recent years. These results provide empirical evidence supporting the speculation that publication requirements and expectations have risen over time in the field of ecology and evolutionary biology in Taiwan, in line with many academic job markets worldwide (Rawat and Meena 2014; Warren 2019).

The increase in academic performance of PIs before recruitment suggests that the academic job market might have 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 (Larson et al. 2014). Consequently, the duration post-PhD may be prolonged if the applicants are not competitive enough. Furthermore, PIs with Taiwanese PhD degrees tended to have longer duration before recruitment, which may result from employment institutions favoring applicants with foreign degrees. Under the increasing competition for limited faculty positions, it would be important for early-career researchers to hone in on publications in order to demonstrate their academic competence.

The performance of PIs before promotion to full professor also increased over years, but the rate of increase was lower than that during recruitment phase, indicating that the publication requirements for promotion might not have changed much over time compared to the requirements for recruitment. This may be partially due to increasing consideration of accomplishments such as teaching and administrative

services by employment institutions in addition to research outputs. Overall, the differences in the temporal patterns of academic performance and career duration between recruitment and promotion phase are likely due to the nature of recruitment and promotion process: applicants are facing increasing competition with others during recruitment and thus higher publication performance would be advantageous for securing a position, whereas getting a promotion depends mainly on individual PIs meeting the institution's requirements rather than comparing against others' performance. Therefore, publication performance may have less impact during the promotion phase compared to the recruitment phase.

We found that the average performance of new male PIs was higher than that of new female PIs. This may result from higher standards for evaluating the suitability of a potential faculty member for males compared to females (Symonds et al. 2006). Alternatively, it could be due to employment institutions striving to recruit female applicants to enhance gender equity despite the likelihood of female applicants having lower performance than their male competitors, which can be exacerbated by implicit bias and stereotype threats that females face in biological sciences (Salerno et al. 2019). In contrast, the performance expectations for promotion to full professor did not differ between male and female PIs, suggesting that individual performance is the key to further promotion after recruitment regardless of gender, especially when gender equality is enhanced.

Contrary to a previous study showing that researchers from higher-ranked institutions became PIs faster compared to those from lower-ranked institutions (van Dijk et al. 2014), we found no evidence of PhD university ranking influencing the

career duration either before recruitment or before promotion. Instead, the academic performance during PhD and/or post-PhD period may be more important in determining the academic success compared to PhD prestige itself.

The difference in performance before and after recruitment decreased over years. Specifically, PIs in earlier years had on average higher h-indexes after recruitment than before recruitment, yet such a “performance boost” has declined recently. This could arise from increasing teaching and administrative loading of new PIs in recent years, which may have reduced their available time for research. Moreover, PIs with Taiwanese PhD degrees appeared to exhibit a decrease in performance after promotion to full professor compared to before promotion, whereas PIs with foreign PhD degrees had relatively consistent performance before and after promotion. A 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, help maintain their research performance.

It is noteworthy that recruitment is a complicated process involving not only academic performance *per se* but also other considerations such as the suitability of applicants to the research areas of opening positions. Although our study showed increasing academic performance expectations for recruitment over years, we do not intend to discourage the academic community with such results. Indeed, variations in h-index during the recruitment phase indicate that it is still possible for an applicant with a relatively low h-index to land a position. Moreover, besides research performance, other aspects of academic achievements, including teaching,

mentoring, and social outreach, also constitute a significant part of a researcher's career, and we stress that balancing these different aspects would be necessary for a more holistic professional development. Finally, our analyses were based on PIs in ecology and evolutionary biology, within which variations in publication performance and citation patterns may exist. Since the nature of academic job markets can vary considerably among different sub-fields of biology (Larson et al. 2014), the results herein should be interpreted carefully when applied to the fields outside the scope of this study.

Taken together, our study confirms that succeeding in academia has become more challenging, with performance requirements and career duration both increasing over years. Based on our findings, we provide several suggestions for researchers who hope to pursue an academic career and who are progressing through their career stages: (1) For PhD students and early-career researchers, focusing on publication outputs may facilitate future academic success, but other aspects of academics (e.g., scientific communication and networking) are important as well. (2) For researchers who have landed a position, fulfilling institution's requirements while maintaining academic outputs may accelerate the promotion process. (3) For researchers with domestic PhD degrees, seeking international collaboration to expand research network may help enhance productivity. Finally, regardless of career stage, boosting research performance is the ultimate key to academic success in the face of increasingly competitive academic job markets.

Statements and Declarations

- **Competing interests**

The authors declare no competing interests.

- **Footnotes**

Please note that this manuscript has also been posted on *bioRxiv* (Hsu et al. 2022) at https://www.biorxiv.org/content/10.1101/2022.01.31.478501v2, following the Springer Nature preprint sharing policy. It has also been added to the reference list.

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- **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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Tables and Figures

Table 1. Results of the GLMMs/LMMs for academic performance before recruitment/promotion, career duration before recruitment/promotion, and difference in performance before and after recruitment/promotion. *n* represents the sample size in each model. The upper and lower 95% confidence limit (CL) of each regression coefficient (*β*) was derived from 1000 bootstrap samples

Model	*n*	Response	Predictor	*β*	SE	Lower 95% CL	Upper 95% CL	χ^2	*d.f.*	*P*
Model 1. Academic performance (recruitment)	134	"Before" h-index (recruitment)	Year of recruitment	0.0431	0.0004	0.0302	0.0494	4658.02	1	< 0.001
			PhD university origin (Taiwan)	-0.0696	0.1094	-0.1862	0.1527	0.03	1	0.855
			PhD university ranking	0.0001	0.0002	-0.0003	0.0003	0.13	1	0.721
			Gender (Male)	0.4590	0.1314	0.2107	0.6590	15.52	1	< 0.001
Model 2. Academic performance (promotion)	59	"Before" h-index (promotion)	Year of promotion	0.0105	0.0007	-0.0040	0.0234	224.28	1	< 0.001
			PhD university origin (Taiwan)	-0.1721	0.1119	-0.3935	0.0443	2.36	1	0.124
			PhD university ranking	-0.0001	0.0002	-0.0003	0.0003	0.00	1	0.977
			Gender (Male)	-0.1559	0.1318	-0.3667	0.0859	1.40	1	0.237
Model 3. Career duration (recruitment)	134	Duration before recruitment	"Before" h-index (recruitment)	0.0176	0.0135	-0.0134	0.0418	1.71	1	0.191
			Year of recruitment	0.0369	0.0063	0.0241	0.0491	33.99	1	< 0.001
			PhD university origin (Taiwan)	0.1914	0.1004	-0.0095	0.3780	3.63	1	0.057
			PhD university ranking	-0.0002	0.0002	-0.0006	0.0001	1.72	1	0.190
			Gender (Male)	-0.0997	0.1179	-0.3379	0.1306	0.72	1	0.398

Model 4. Career duration (promotion)	57	Duration before promotion	"Before" h-index (promotion)	-0.0176	0.0106	-0.0371	0.0051	2.77	1	0.096
			Year of promotion	0.0124	0.0064	-0.0005	0.0242	3.74	1	0.053
			PhD university origin (Taiwan)	0.0844	0.0957	-0.0990	0.2747	0.78	1	0.378
			PhD university ranking	-0.0002	0.0002	-0.0005	0.0001	1.33	1	0.249
			Gender (Male)	-0.1052	0.1054	-0.3115	0.1121	1.00	1	0.318
Model 5. Difference in performance (recruitment)	101	"After" h-index minus "Before" h-index (recruitment)	Year of recruitment	-0.1807	0.0492	-0.2793	-0.0833	13.50	1	< 0.001
			PhD university origin (Taiwan)	-0.1784	0.9059	-1.9855	1.5559	0.04	1	0.844
			PhD university ranking	0.0011	0.0015	-0.0019	0.0041	0.56	1	0.456
			Gender (Male)	-0.1047	0.9949	-2.1267	1.7896	0.01	1	0.916
Model 6. Difference in performance (promotion)	47	"After" h-index minus "Before" h-index (promotion)	Year of promotion	-0.1614	0.0985	-0.3580	0.0333	2.69	1	0.101
			PhD university origin (Taiwan)	-2.0458	1.2024	-4.3170	0.4247	2.90	1	0.089
			PhD university ranking	0.0017	0.0019	-0.0021	0.0053	0.83	1	0.362
			Gender (Male)	0.7120	1.3545	-1.9329	3.4744	0.28	1	0.599

Figure 1. Distribution of the universities from which the 145 PIs obtained their PhD degrees. Percentages of PhD degrees obtained from the USA, Taiwan, and the UK are as noted; “Other” includes all the other countries with percentages less than 4.0%.

Figure 2. Distribution of the ranking of universities from which PIs obtained their PhD degrees. Dashed lines indicate the medians of university ranking for PIs with foreign degrees (median ranking = 108 out of 97 PIs) and Taiwanese degrees (median ranking = 252 out of 48 PIs).

Figure 3. Temporal trends in academic performance and career duration before recruitment and promotion. Each point represents an individual PI; solid lines represent significant relationships (*P* values are from the GLMMs); shaded areas indicate 95% confidence intervals. Note that female and male PIs are shown in separate lines in panel (a) (GLMM gender: $P < 0.001$).

Figure 4. Difference in academic performance before and after recruitment/promotion (“After” h-index minus “Before” h-index) in relation to year of recruitment/promotion (a and c) and PhD university origin (b and d). Each point represents an individual PI; solid/dashed line represents significant/non-significant relationship (*P* values are from the LMMs); shaded area indicates 95% confidence interval.

Figure 1.

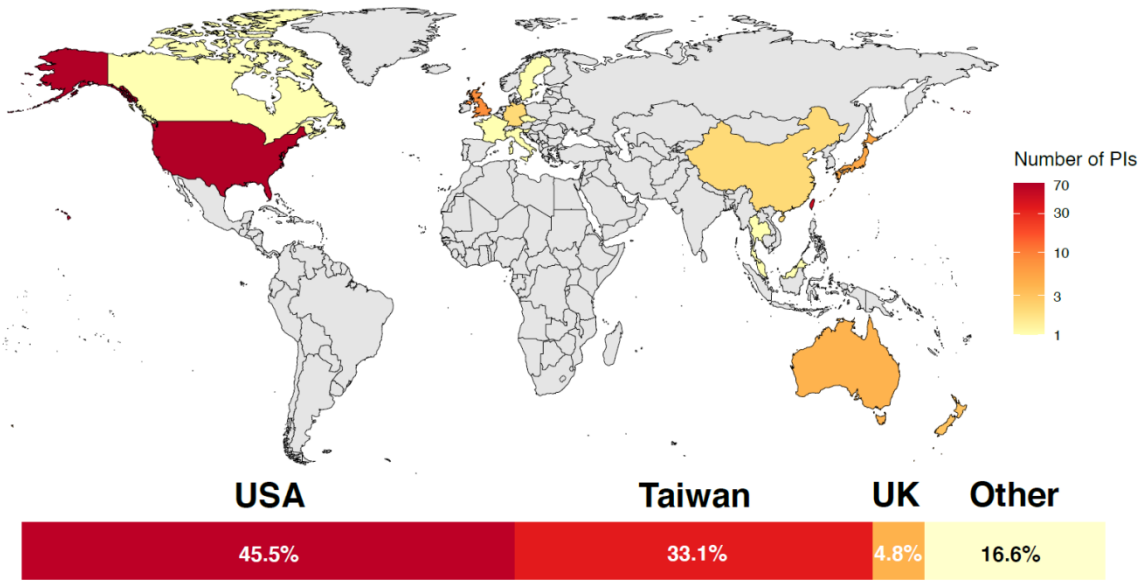


Figure 2.

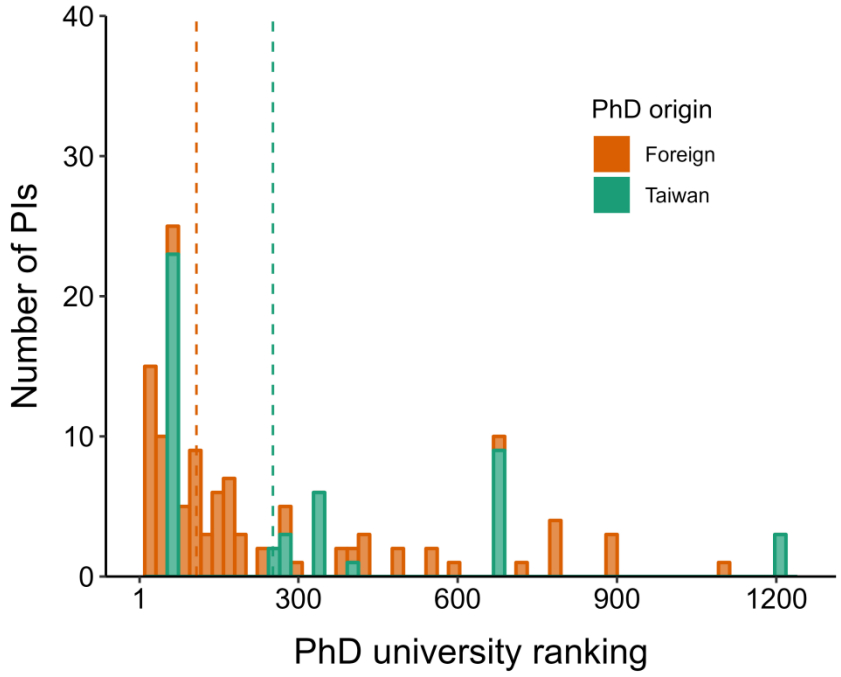

PhD origin
Foreign
Taiwan
Number of PIs
PhD university ranking
0
10
20
30
40
1
300
600
900
1200

Figure 3.

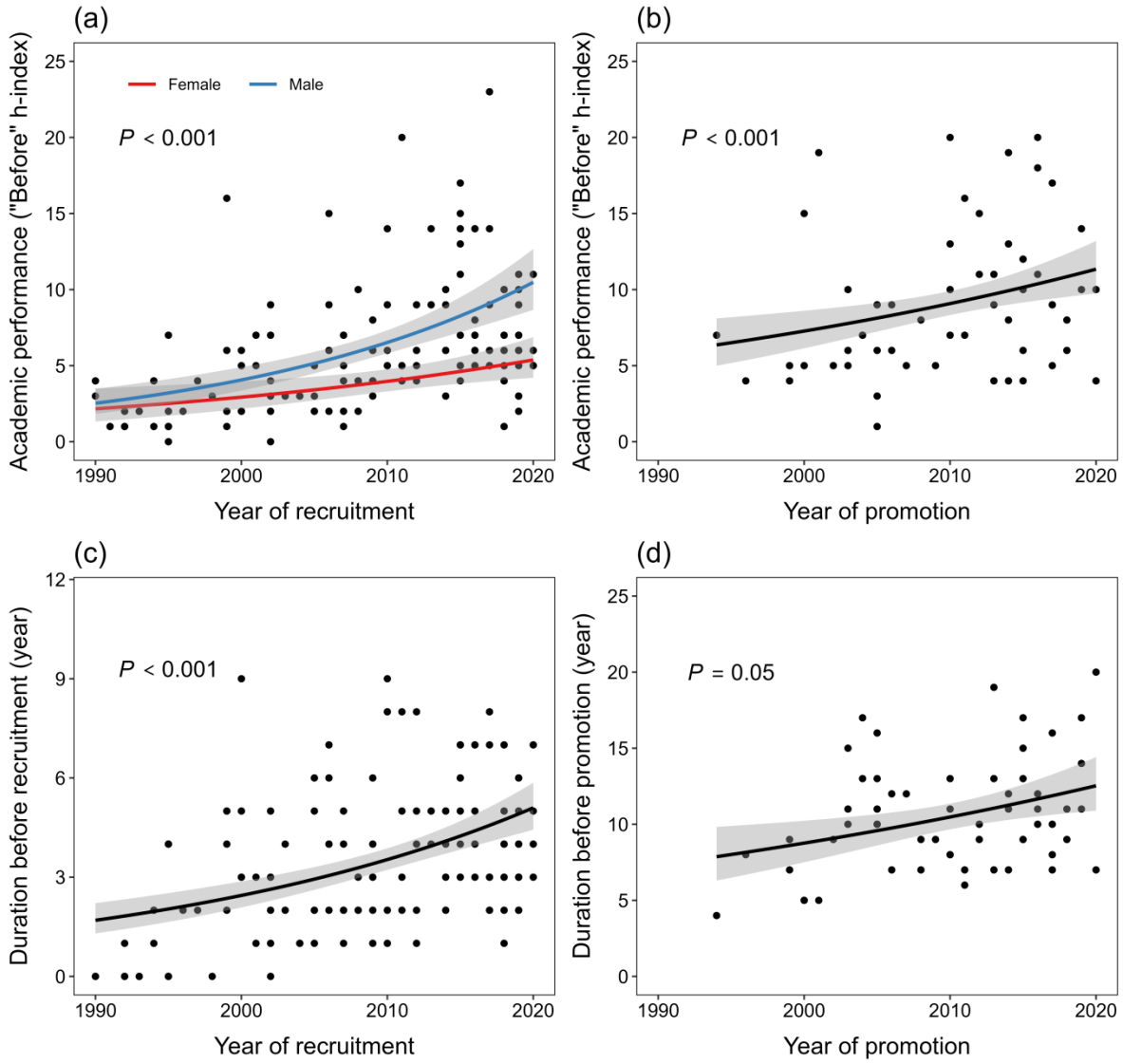
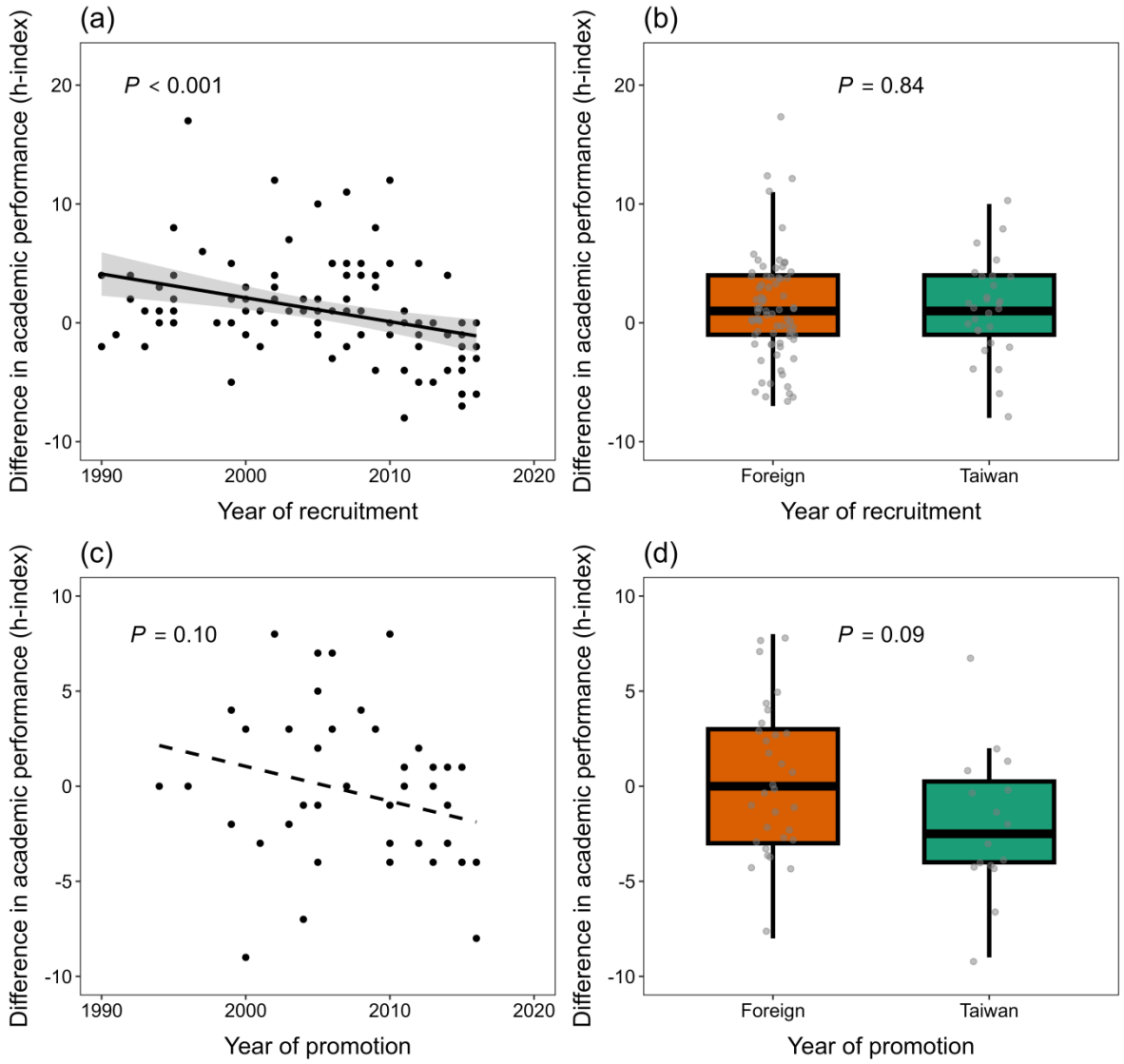

(a)
Female
Male
P < 0.001
Academic performance ("Before" h-index)
Year of recruitment
(b)
P < 0.001
Academic performance ("Before" h-index)
Year of promotion
(c)
P < 0.001
Duration before recruitment (year)
Year of recruitment
(d)
P = 0.05
Duration before promotion (year)
Year of promotion

Figure 4.


(a)
P < 0.001
Difference in academic performance (h-index)
Year of recruitment
(b)
P = 0.84
Foreign
Taiwan
Year of recruitment
(c)
P = 0.10
Year of promotion
(d)
P = 0.09
Foreign
Taiwan
Year of promotion

The number of book/book chapters excluded for each PI

Updated dataset excluding book/book chapters