Scientometrics

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

--Manuscript Draft--

Manuscript Number:	SCIM-D-22-00945R2
Full Title:	Temporal trends in academic performance and career duration of principal investigators in ecology and evolutionary biology in Taiwan
Article Type:	Manuscript
Keywords:	academic job market; academic performance; career duration; h-index; principal investigator; publication
Corresponding Author:	Syuan-Jyun Sun National Taiwan University Taipei, TAIWAN
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	National Taiwan University
Corresponding Author's Secondary Institution:	
First Author:	Gen-Chang Hsu
First Author Secondary Information:	
Order of Authors:	Gen-Chang Hsu
	Wei-Jiun Lin
	Syuan-Jyun Sun
Order of Authors Secondary Information:	
Funding Information:	National Science and Technology Council (MOST 2030 Cross-Generation Young Scholars Program (111-2628-B-002-050-)) — Dr Syuan-Jyun Sun
	National Taiwan University (NTU New Faculty Founding Research Grant) — Dr Syuan-Jyun Sun
	Ministry of Education (Yushan Fellow Program) — Dr Syuan-Jyun Sun
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 (PI) 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. Similarly, the career duration before recruitment and before promotion both increased in recent years. Moreover, PIs with Taiwanese PhD degrees tended to have longer duration before recruitment, yet higher performance shortened the duration. PhD university ranking had no effect on performance and duration either before recruitment or before promotion. We also found that PIs recruited in recent years exhibited a performance drop post-recruitment. Furthermore, PIs with Taiwanese PhD degrees appeared to show a decrease in performance after promotion compared to those with foreign degrees. Taken together, our study reveals increasing academic performance and career duration of PIs in ecology and evolutionary biology in Taiwan over the last three decades, and highlights the crucial role of research performance,

	rather than the PhD prestige itself, in determining academic success.
Response to Reviewers:	Response to Reviewers' Comments Date: January 11, 2023 Manuscript Number: SCIM-D-22-00945R1 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 Email: 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. We have incorporated many of the suggestions and the revision has substantially improved the manuscript. In particular, we have made the following major changes: •Revised/added two paragraphs in the introduction section for a review of past studies on this topic to provide more background information regarding the current state of the research. •Added a paragraph in the methods section detailing the searching process and data handling in the Publish or Perish software. •Added a paragraph in the methods section discussing the advantages and disadvantages of performing citation search using Google Scholar Profiles. •Added a paragraph in the methods section discussing the use of h-index as a measure of academic performance in our study. •Re-analyzed the data and updated the statistical analyses, results, and discussion. •Added a concluding paragraph in the discussion section providing practical advice and suggestions for people who hope to pursue an academic career and who are currently progressing through their career stages. •Revised Table 1 by providing more details on the models results and fit measures (model specifications, sample sizes, regression coefficients, standard errors, 95% confidence limits). •Updated the figures based on the results of the re-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 1's Comments to the Author(s): This article collects various types of open data and investigates the academic job market in Taiwan, which is an important topic deserving further future studies. However, there are some questions or suggestions as follows: (1) About data collection Comment 1 > In line 123 to 126, this research includes 145 PIs who had an updated CV. In other words, researchers who hadn't updated CV were excluded and those PIs' academic careers whether represent specific patterns or not. Hence, what's the representativeness of these 145 PIs in this study? Response > In most cases, we were able to obtain the PhD education as well as year of recruitment/promotion of PIs on their personal or department/institute websites (these are the most basic information of researchers' profile). For those PIs with missing information on the websites, we would further search their profile online and record the necessary information to complete our data. In total, there were only 7 out of 152 (4.6%) PIs whose CV information we would not be able to obtain online. The final data included 145 PIs from seven major universities and one research institute; therefore, we feel that our data should be fairly representative of the PIs in ecology and evolutionary biology in Taiwan. Comment 2 > Besides the institutional/departmental websites, and ORCID, other open data or database could be further consideration, such as Web of Science, Scopus, or

Academic Research Service Portal Researcher Query of National Science and Technology Council.
Response > Thanks for the suggestion. Yes, these websites are great sources for PIs' profile. Indeed, as mentioned in the response to Comment 1, we were able to obtain the necessary information for most PIs through their personal or department/institute websites and ORCID sites.

(2) About literatures
Comment 3 > This study includes those variables such as year of recruitment, gender, PhD university origin, PhD university ranking, year of promotion and so on (shown as Table 1). What's the theoretical basis of relationship between those variables? If this article supplied the section of literature review, readers would more understand the existing related researches of this topic even the theoretical basis.
Response > Thanks for the suggestion. We agree that it would be helpful to provide some background information so that the readers can get a better idea of the research context. We have now included the following two paragraphs (Line 82-90; Line 92-106) in the introduction section:
"Previous studies have focused on how various bibliometric indicators predict researchers' future academic excellence and scientific contributions. The number of publications, top journal publications, publication rates, the number of distinct journals, and the number of citations are all important determinants of academic performance (Acuna et al. 2012; Danell 2011; Lindahl 2018). Academic performance is critical for researchers' future 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 performance affects the duration before recruitment and promotion over time remains unexplored."
"In addition to research performance, the prestige of doctoral-granting institutes are critical indicators for academic employment as well (van Dijk et al. 2014), especially in East Asian countries (Shin and Kehm 2013). With the initiative to build world-class universities, many East Asian universities preferentially recruit returnees who obtained PhD degrees from top-ranked universities in Western countries. 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 unexplored. Moreover, studies have shown that the researcher's gender determines the probability of becoming a principal investigator (PI) (van Dijk et al. 2014) and receiving grants (Witteman et al. 2019), yet little is known about how gender affects the publication performance and career duration for recruitment and promotion."

Comment 4 > According to the results and discussions, what's the concrete suggestions to higher education policy, recruitment of university's teaching and research staffs, or PhD students who aim to academic careers?
Response > Thanks for this critical comment. A major goal of our study is to provide practical advice for people in the academic community. We have now added the following concluding paragraph in the discussion section for this (Line 372-384):
"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 people 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 research performance 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 institute's requirements while maintaining academic outputs may accelerate the promotion process. (3) For researchers with domestic degrees, seeking international collaboration to expand research network may help enhance productivity. Finally, regardless of career stage, boosting performance is the ultimate key to academic success in the face of increasingly competitive academic job markets."

Reviewer 2's Comments to the Author(s):
Comment 1 > The authors examine "how academic performance as well as duration before recruitment as a new principal inverstigator (PI) and promotion to full professor

changed over time, and how PhD university origin, PhD university ranking, and gender affected the career success". The manuscript has potential to make a contribution to the literature. However, the manuscript has some problems which makes me recommend major revision. Hopefully my questions and comments can help the authors to improve the manuscript.
Response > Thanks for the positive attitude towards this study. We have revised our manuscript based on the following comments and incorporated many of the suggestions provided.

Title
Comment 2 > The title does not really convey what the study is about.
Response > We have now changed our title after the revision: ”Temporal trends in academic performance and career duration of principal investigators in ecology and evolutionary biology in Taiwan”.

Abstract
Comment 3 > The first sentence in the 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" seem unsubstantiated. There are numerous studies that have examined determinants of academic success (see. e.g., Hirsch, 2007; Danell, 2011; Acuna et al., 2012; Havemann and Larsen, 2015; Bornmann and Williams, 2017a; Lindahl, 2018). My recommendation is that the authors include a more extensive literature review on previous research in the field and provide a more accurate and nuanced summary of the state of this research.
Response > Thanks for the suggestion. We have now revised the first part of the abstract and revised/added two paragraphs in the introduction section to provide more background information of the topic so that the readers can get a better idea of the research context (also see our response to Comment 3 from Reviewer 1).
•Revised abstract (Line 25-29):
“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.”

•Revised/added paragraphs in the introduction section (Line 82-90; Line 92-106):
“Previous studies have focused on how various bibliometric indicators predict researchers’ future academic excellence and scientific contributions. The number of publications, top journal publications, publication rates, the number of distinct journals, and the number of citations are all important determinants of academic performance (Acuna et al. 2012; Danell 2011; Lindahl 2018). Academic performance is critical for researchers’ future 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 performance affects the duration before recruitment and promotion over time remains unexplored.”
”In addition to research performance, the prestige of doctoral-granting institutes are critical indicators for academic employment as well (van Dijk et al. 2014), especially in East Asian countries (Shin and Kehm 2013). With the initiative to build world-class universities, many East Asian universities preferentially recruit returnees who obtained PhD degrees from top-ranked universities in Western countries. 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 unexplored. Moreover, studies have shown that the researcher’s gender determines the probability of becoming a principal investigator (PI) (van Dijk et al. 2014) and receiving grants (Witteman et al. 2019), yet little is known about how gender affects the publication performance and career duration for recruitment and promotion.”

Materials and Methods
Measurement of academic performance
Comment 4 > The data collection with the Publish or Perish software for the h-index

need to be described and presented much more and in greater detail. There is not enough detail to be able to review the data collection or the data for calculating the h-index. As a reader I'm not sure how the authors collected the publications for the authors. Did they conduct searches through Publish or Perish at the publication level or the author level? How was the search queries formulated, i.e., did the authors conduct searches on the basis of publication titles, persistent identifiers, etc? My recommendation is (1) that the authors provide the search queries in the manuscript or as an appendix and (2) that they provide much more detail about the data collection procedure and what they have done including how they handle the CV data etcetera.
Response > We have added a paragraph in the methods section detailing our searching process and data handling in the Publish or Perish software (Line 146-161): "We collected citation data on PIs via the Publish or Perish software, which uses Google Scholar Profile 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 author 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 papers and book chapters regardless of authorship (PhD theses and conference presentations were excluded). Separate result items that indeed referred to a single article or a book were merged into one entry. We also cross-referenced the result items with the updated curriculum vitae online to ensure the accuracy of search results. The final citation metrics were then exported for further statistical analyses."

Comment 5 > I cannot see how many documents that are included in the final dataset? This should be included in the manuscript.
Response > As mentioned in the methods section, our final dataset includes 145 PIs from seven major universities and one research institute in Taiwan. The data compilation process consisted of two phases:
Phase 1: We visited the department/institute websites and/or ORCID sites to obtain information on the PhD education and year of recruitment/promotion of PIs in ecology and evolutionary biology. 145 PIs were identified and recorded in the phase.
Phase 2: For each of those 145 PIs, we entered the name in the Publish or Perish software to retrieve the publication information and related citation metrics, exported the results, and combined them with the data obtained in Phase 1.
There are no actual "documents" in the final dataset, but rather it incorporates the PIs' information obtained from the websites as well as the Publish or Perish software.

Comment 6 > What do the authors mean with "regardless of authorship for" in the sentence on page 7 row 1-3?
Response > By "regardless of authorship for", we mean that we included any publications of the PI for the calculation of h-index, regardless of whether the PI was the first author, co-author, or corresponding author. We have changed the original expression to "regardless of authorship" (Line 156).

Comment 7 > The authors use the h-index to measure research performance. The h-index is not a normalized indicator of research performance, i.e., it do not adjust for, e.g., research area, publication year, and publication type, and do not live up to best practice in scientometric research. See e.g., Waltman (2016) for a review of citation indicators. To use non-normalized bibliometric indicators as measures of research performance can lead to severe biases in the analyses. The h-index has been heavily criticized in the scientometric literature (Bornmann, & Daniel, 2007; Bornmann, & Daniel, 2009) and it is not recommended to use to measure research performance at the individual level (Waltman, & Van Eck, 2012). My recommendation is that the authors change their dependent variable to a normalized bibliometric indicator that is in accordance with best practice in scientometric research or provide good arguments for why the use of h-index should be used in this case. Another potential solution is to use a variation of the h-index that adjust for the problems with the h-index and fit the context of the authors study (see e.g., Alonso et al., 2009, for a review of h-index and its variant).
Response > Thanks for pointing out this issue. We agree that there are several

drawbacks of h-index. However, we still elected to use it in our re-analyses for the following reasons:
•Advantages of h-index:
1.h-index is robust to highly- and lowly-cited publications and thus is suitable for evaluating the overall impact of a researcher's outputs (Bornmann and Daniel 2007).
2.The original h-index is more straightforward and readily available on various academic search engines compared to the alternative normalized versions.

•Concerns about h-index (Waltman 2016):
1.h-index varies among research areas: Our study focuses on PIs within the field of ecology and evolutionary biology and therefore their h-indexes should be fairly comparable.
2.h-index depends on the publication year: We restricted our publication search of PIs to five years before/after recruitment/promotion so that their h-indexes can be compared at the same time interval.
3.h-index varies among publication types: By including both journal articles and book (chapters) in the calculation of h-index rather than calculating h-indexes separately for each of them, the potential variations in h-index among the two publication types were reduced.
We have added a discussion of the use of h-index in our analyses in the methods section (Line 181-186):
"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."
References:
Bornmann, L. & Daniel, H. D. (2007). What do we know about the h index?. Journal of the American Society for Information Science and technology, 58, 1381-1385.
Waltman, L. (2016). A review of the literature on citation impact indicators. Journal of informetrics, 10(2), 365-391.

Comment 8 > The authors need to discuss the pros and cons of using google scholar. Why use Google Scholar instead of a citation database, e.g., Scopus or the citation indices accessible through Web or Science? Harzing state that Web of Science and Scopus have higher accuracy so why not use them (see https://harzing.com/resources/publish-or-perish/manual/using/query-results/accuracy)? How might the use of Google Scholar affect the results? The authors should provide a discussion in the manuscript where the pros and cons of using Google Scholar become transparent for the reader.
Response > Thanks for the suggestion. The main advantages of Google Scholar Profiles over other academic search engines are its comprehensiveness in publication coverage (and thus more citations) and its free access (Martín-Martín et al. 2018; Martín-Martín et al. 2021). In fact, these were the reasons why we chose to perform citation search using Google Scholar Profiles rather than Web or Science or Scopus (which are paid services).
A major weakness of Google Scholar Profiles is that the quantity and quality of metadata for researchers' publications are relatively lower compared to Web or Science or Scopus (Waltman 2016). However, this is not a limitation to our study because we did not use publication metadata in our analyses. In fact, according to Martín-Martín et al. (2021), "the final decision about which source to use may depend on properties of the sources other than coverage, such as metadata quality and bulk access options. If these factors are not of overriding importance, however, then Google Scholar is the best choice in almost all subject areas for those needing the most comprehensive citation counts but not needing complete lists of citing sources."
We have added a paragraph in the methods section discussing the advantages and disadvantages of performing citation search using Google Scholar Profiles (Line 163-172):
"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 and DOI) 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."
References:
Martín-Martín, A., Orduna-Malea, E., Thelwall, M. & López-Cózar, E. D. (2018). Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. Journal of informetrics, 12, 1160-1177.
Martín-Martín, A., Thelwall, M., Orduna-Malea, E. & Delgado López-Cózar, E. (2021). Google Scholar, Microsoft Academic, Scopus, Dimensions, Web of Science, and OpenCitations' COCI: a multidisciplinary comparison of coverage via citations. Scientometrics, 126, 871-906.
Waltman, L. (2016). A review of the literature on citation impact indicators. Journal of informetrics, 10, 365-391.

Statistical analyses
Comment 9 > CV data usually comes with a lot of missing values. However, I cannot find anything about missing values in the text. Is there no missing values in the data? If there are missing values a wonder how have the authors handled the missingness.
Response > Thanks for bringing up this issue. Yes, for the 145 PIs in our final dataset, some of them had missing values for certain response variables, and only those with full information were used in each respective model. For example, a PI who is currently an associated professor will have performance and duration data for recruitment but not promotion. This PI will be included in the analyses of recruitment (Model 1, 3, and 5 in Table 1) but excluded in the analyses of promotion (Model 2, 4, and 6 in Table 1). We have added a column to Table 1 to denote the actual sample size (n) in each model.

Comment 10 > Regarding the LMMs the authors are referencing R-packages which is fine. But I recommend the authors to also provide relevant references for the actual methods they use.
Response > We have added a citation for GLMM/LMM to the statistical analyses (Line 208-209):
"we fit generalized linear mixed models (GLMMs) (Bolker et al. 2009) with …"
Reference:
Bolker, B. M., Brooks, M. E., Clark, C. J., Geange, S. W., Poulsen, J. R., Stevens, M. H. H., & White, J. S. S. (2009). Generalized linear mixed models: a practical guide for ecology and evolution. Trends in ecology & evolution, 24, 127-135.

Comment 11 > What do the authors mean with the following sentence: "Non-significant interactions ($p > 0.05$) were dropped from our final model results. Did the authors first try all possible interactions for each model and then in the final models they only included the significant interactions. Or did the authors include all interactions in the final model but only show the significant interaction in the results (i.e., Table 1)?
Response >
In our original analyses, we first tested all interactions, dropped the non-significant ones, and refit the final model using only the significant interaction terms. So the results in the original Table 1 represented all the terms (main effects and interactions) in the models. However, we have now re-analyzed our data and included only the main effects of predictors in the models because most models do not have significant interactions, and focusing on the main effects can facilitate the interpretation of the results as well as the comparisons between different models.

Comment 12 > The authors write that they log-transformed the dependent variables "to meet the assumption of normality". (page 9, row190-191). Did the authors test the assumption of normality on the transformed variables?
Response >
We have now re-analyzed the data in our revision. For the academic performance and career duration models (Model 1-4), we did not log-transform the responses but fit GLMMS with a Poisson error distribution and a log link function, as the h-index and year duration are all non-negative integers. For the difference in performance models (Model 5 and 6), we fit LMMs with a Gaussian error distribution and an identity link function, as the difference can take positive, zero, or negative values.
The statistical analyses in the results section were updated (Line 206-242):

	“(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 institute (department) nested within university as random effects. The GLMMs were fitted with a Poisson error distribution and a log link function as the response is non-negative integers. (2) Duration before recruitment/promotion (Model 3 and 4). To examine how various factors affect 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 the institute (department) nested within university as random effects. The GLMMs were fitted with a Poisson error distribution and a log link function as the response is non-negative integers. (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 institute (department) 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 “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 assumption of equal variance and normality were assessed using residual plots and QQ-plots. Significance ($\alpha = 0.05$) of model coefficients were tested (Wald chi-square test) using the Anova() function in the “car” package (Fox and Weisberg 2019). All analyses were performed in R version 4.2.2 (R Development Core Team 2022).” For each model, the assumption of equal variance and normality were both checked using a residual plot and a QQ-plot (the below plots were generated using the R package “performance”): Model 1 Model 2 Model 3 Model 4 Model 5 Model 6 Overall, there is no severe violation of the assumptions. The residuals in Model 5 seem to deviate from the line at the top-right corner. Nonetheless, this should not be a major issue as studies have shown that regression models are fairly robust to moderate degree of non-normality (Knief and Forstmeier 2021; Schielzeth et al. 2020). References: Knief, U. & Forstmeier, W. (2021). Violating the normality assumption may be the lesser of two evils. Behavior Research Methods, 53, 2576-2590. Schielzeth, H., Dingemanse, N.J., Nakagawa, S., Westneat, D.F., Allegue, H., Teplitsky, C., Réale, D., Dochtermann, N.A., Garamszegi, L.Z. & Araya-Ajoy, Y.G.

(2020). Robustness of linear mixed-effects models to violations of distributional assumptions. Methods in ecology and evolution, 11, 1141-1152.

Results
Comment 13 > The authors should provide descriptive statistics for their data and variables. Either in the results section or in the Materials and Methods section. This is important so that the reader can get an overview of the data and its properties.
Response > We did provide an overview of our data in the first paragraph of the original manuscript (now at Line 245-252 in the revised manuscript).

Comment 14 > The authors should be clearer about how they use p-values and how they interpret them, especially since their data is not a random sample. For example, the authors write that "PhD university origin, ranking, and gender had no effect on the duration either before recruitment or before promotion (page 10, row 49-54). In Table 1 I can observe that, e.g., the coefficient for the "PhD university origin" is 3.48 which indicates a positive effect and that the p-value is 0.06. I take it that the chosen significance level in the manuscript is 0.05. 0.06 is not that much higher than 0.05. From my perspective I would say that there is a positive effect but that the p-value indicates that there are some uncertainty and that interpretation should therefore be done with some caution. There are two issues here. First, how does the authors define and use p-values in the manuscript? This is not clear. Second, the sample is not a random sample so it seems a bit strange to be super strict about the p-values and e.g., conclude that there is an effect if the p-value is 0.04999 and conclude that there is no effect of the p-value is 0.05, regardless of the size of the coefficient, taking sample size into consideration, etc. The use of p-values does in either case not live up to the required assumptions for making real inference due to the non-random sample. Overall (i.e., this is a recommendation for all the results and not just for the example I provided regarding the "PhD university origin"). The sample size is small (N = 145) and a larger sample size would likely produce significant results. My suggestion for the authors is to adopt a less dichotomous and more nuanced strategy for interpreting the results of their analyses, e.g., using confidence intervals for determining uncertainty together with the p-values, and not dogmatically approve or disprove of an effect just by looking at the p-values.
Response > Thanks for bringing up the issue of interpreting the results based on p-values and the suggestion for it. Yes, our significance level was set at 0.05 (Line 240). To avoid the arbitrary cutoff at p = 0.05, for those regression coefficients with p-values between 0.05 and 0.10, instead of simply stating no effects, we now describe the predictor effects in our results and use “tended to” or “although not statistically significant” to indicate that the p-values are not below 0.05 yet there is still some statistical support for the effects. These include:
•“PIs with Taiwanese PhD degrees tended to have longer durations before recruitment” (Line 268-269) [p = 0.08]
•“The difference in performance before and after promotion to full professor, although not statistically significant, also decreased over years” (Line 280-282) [p = 0.09]
•“the difference tended to be higher for PIs with foreign degrees compared to those with Taiwanese degrees” (Line 282-283) [p = 0.06]
Additionally, we have added the 95% confidence limits to Table 1 to show the uncertainty around the regression estimates (also see our response to Comment 17).

Comment 15 > Can the authors complement the analyses with effect sizes so that it become easier for the reader to understand the size of the effects?
Response > Thanks for the suggestion. We have added the regression coefficients (β) of the predictors to Table 1.

Comment 16 > Can the authors transform back the coefficients so that it becomes easier to interpret the actual effects.
Response > We have re-analyzed our data and no response was log-transformed in any of the models (also see our response to Comment 10 for more details regarding model fitting).

Comment 17 > I believe that there is to little information in Table 1 regarding the models and outcomes. As a reader it is difficult to properly assess the results of the analysis. Standard errors and confidence intervals should be included. Some kind of model of fit measure should be included.

	Response > Thanks for the suggestion. We have added the standard errors and 95% confidence limits of the regression coefficients to Table 1. Comment 18 > As I understand it Table 1 present 6 models. This should be more clearly presented in the table, i.e., that each dependent variable in the first column denotes a specific model. Response > Thanks for the suggestion. Yes, there were a total of 6 models in our analyses. We have added a first column to Table 1 denoting each model. References provided by Reviewer 2 Acuna, D. E., Allesina, S., & Kording, K. P. (2012). Predicting scientific success: Daniel E. Acuna, Stefano Allesina and Konrad P. Kording present a formula to estimate the future h-index of life scientists. Nature, 489(7415), 201-202. https://doi.org/10.1038/489201a Alonso, S., Cabrerizo, F. J., Herrera-Viedma, E., & Herrera, F. (2009). h-Index: A review focused in its variants, computation and standardization for different scientific fields. Journal of informetrics, 3(4), 273-289. Bornmann, L., & Daniel, H. D. (2007). What do we know about the h index?. Journal of the American Society for Information Science and technology, 58(9), 1381-1385. Bornmann, L., & Daniel, H. D. (2009). The state of h index research: Is the h index the ideal way to measure research performance?. EMBO reports, 10(1), 2-6. Bornmann, L., & Williams, R. (2017). Can the journal impact factor be used as a criterion for the selection of junior researchers? A large-scale empirical study based on ResearcherID data. Journal of Informetrics, 11(3), 788-799. https://doi.org/10.1016/j.joi.2017.06.001 Danell, R. (2011). Can the Quality of Scientific Work Be Predicted Using Information on the Author's Track Record? Journal of the American Society for Information Science and Technology, 62(1), 50-60. https://doi.org/10.1002/asi.21454 Havemann, F., & Larsen, B. (2015). Bibliometric indicators of young authors in astrophysics: Can later stars be predicted? Scientometrics, 102(2), 1413-1434. https://doi.org/10.1007/s11192-014-1476-3 Hirsch, J. E. (2007). Does the h index have predictive power? Proceedings of the National Academy of Sciences, 104(49), 19193-19198. https://doi.org/10.1073/pnas.0707962104 Lindahl, J. (2018). Predicting research excellence at the individual level: The importance of publication rate, top journal publications, and top 10% publications in the case of early career mathematicians. Journal of Informetrics, 12(2), 518-533. Waltman, L., & Van Eck, N. J. (2012). The inconsistency of the h-index. Journal of the American Society for Information Science and Technology, 63(2), 406-415.

For submission to Scientometrics

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

Gen-Chang Hsu[1], Wei-Jiun Lin[2], Syuan-Jyun Sun[3,*]

[1]Department of Life Science, National Taiwan University, Taipei, Taiwan

[2]Institute of Ecology and Evolutionary Biology, National Taiwan University, Taipei, Taiwan

[3]International Degree Program in Climate Change and Sustainable Development, National Taiwan University, Taipei 10617, Taiwan

ORCID iD

Gen-Chang Hsu: 0000-0002-6607-4382

Syuan-Jyun Sun: 0000-0002-7859-9346

*Corresponding author: Syuan-Jyun Sun; email: sjs243@ntu.edu.tw

Acknowledgments

We thank Ming-Yang Megan Chang for useful comments on the manuscript. SJS was funded by NTU New Faculty Founding Research Grant, MOST 2030 Cross-Generation Young Scholars Program (111-2628-B-002-050-), and the Yushan Fellow Program provided by the Ministry of Education.

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 (PI) 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. Similarly, the career duration before recruitment and before promotion both increased in recent years. Moreover, PIs with Taiwanese PhD degrees tended to have longer duration before recruitment, yet higher performance shortened the duration. PhD university ranking had no effect on performance and duration either before recruitment or before promotion. We also found that PIs recruited in recent years exhibited a performance drop post-recruitment. Furthermore, PIs with Taiwanese PhD degrees appeared to show a decrease in performance after promotion compared to those with foreign degrees. Taken together, our study reveals increasing academic performance and career duration of PIs in ecology and evolutionary biology in Taiwan over the last three decades, and highlights the crucial role of research performance, rather than the PhD prestige itself, in determining academic success.

Keywords

academic job market, academic performance, career duration, h-index, 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 ([NSF] National Science Foundation 2018).

The intensifying 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). Additionally, 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).

Previous studies have focused on how various bibliometric indicators predict researchers' future academic excellence and scientific contributions. The number of publications, top journal publications, publication rates, the number of distinct journals, and the number of citations are all important determinants of academic performance (Acuna et al. 2012; Danell 2011; Lindahl 2018). Academic performance is critical for researchers' future 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 performance affects the duration before recruitment and promotion over time remains unexplored.

In addition to research performance, the prestige of doctoral-granting institutes are critical indicators for academic employment as well (van Dijk et al. 2014), especially in East Asian countries (Shin and Kehm 2013). With the initiative to build world-class universities, many East Asian universities preferentially recruit returnees who obtained PhD degrees from top-ranked universities in Western countries. 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

unexplored. Moreover, studies have shown that the researcher's gender determines the probability of becoming a principal investigator (PI) (van Dijk et al. 2014) and receiving grants (Witteman et al. 2019), yet little is known about how gender affects the publication performance and career duration for recruitment and promotion.

To address these gaps, we investigated how academic performance as well as duration before recruitment as a new PI and promotion to full professor changed over time, and how PhD university origin, PhD university ranking, and gender may affect the career success, 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 secure a faculty position or get a promotion, as well as to explore the role of PhD university 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. Together, these eight institutes encompassed 34 academic departments/divisions that serve as tenure homes to the field of ecology and evolutionary biology (including ecology, evolution, biodiversity; see Online Resource 1 for more details). We excluded researchers in biomedical sciences because publication rates, performance, and collaboration opportunities can vary considerably among these fields (Laurance et al. 2013). 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, and gender. The university ranking was 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 collected citation data on 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 author 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 papers and book chapters regardless of authorship (PhD theses and conference presentations were excluded). Separate result items that indeed referred to a single article or a book were merged into one entry. We also cross-referenced the result items with the updated curriculum vitae online to ensure the accuracy of 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 and DOI) 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). In fact, 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 might have only one to three such h-indexes depending on their current stages). We used the duration of five years because this time span 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 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 institute (department) nested within university as random effects. The GLMMs were fitted with a Poisson error distribution and a log link function as the response is non-negative integers.

(2) Duration before recruitment/promotion (Model 3 and 4). To examine how various factors affect 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 the institute (department) nested within university as random effects. The GLMMs were fitted with a Poisson error distribution and a log link function as the response is non-negative integers.

(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 institute (department) 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 “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 assumption of equal variance and normality were assessed using residual plots and QQ-plots. Significance ($\alpha = 0.05$) of model coefficients were tested (Wald chi-square test) using the Anova() function in the “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 16 countries (Fig. 2). The gender difference was substantial, with males (112) being around four 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: 0.040 vs. 0.005; 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, while higher academic performance appeared to reduce this duration, although not statistically significant (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 performance or the PhD university origin (Model 4; Table 1). 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 (Model 5; Table 1, Fig. 4b). The difference in performance before and after promotion to full professor, although not statistically significant, also decreased over years (Fig 4c). Moreover, the difference 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 (Model 6; Table 1, Fig. 4d).

Discussion

Overall, we found that the academic performance of PIs before recruited as new faculty members as well as before promoted to full professors both increased over years. We also showed that the career duration before recruitment and before promotion has 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 likely resulted from employment institutes favoring candidates with foreign degrees. However, higher academic performance shortened the time to land a position. Therefore, it would be beneficial for early-career researchers to hone in on publications in order to demonstrate their competence for academic success.

The performance of PIs before promotion to full professor also increased over years, but the rate of increase was lower than that during recruitment, indicating that the publication requirements for promotion might not have changed much over time compared to the requirements for recruitment. Interestingly, the time to full professor has lengthened in recent years, yet higher academic performance did not shorten the

duration as it did during the recruitment phase. This may be partly due to increasing consideration of accomplishments such as teaching and administrative services by employment institutes 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 performance would be advantageous for securing a position faster, whereas getting a promotion depends mainly on individual PI meeting the institutes' requirements rather than comparing against others' performance and thus higher performance may have less impact on promotion.

We found that the average performance of a new male PI was higher than that of a new female PI. 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 institutes 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 institutes became PIs faster compared to those from lower-ranked institutes (van Dijk et al.

2014), we found no evidence of PhD university ranking influencing the career duration either before recruitment or before promotion. Instead, our results suggest that academic performance during PhD and/or post-PhD period may be more important in determining the academic success compared to the prestige of education 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 result 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 show 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 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 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. Since the nature of academic job markets can vary considerably among different 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 people 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 research performance 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 institute's requirements while maintaining academic outputs may accelerate the promotion process. (3) For researchers with domestic degrees, seeking international collaboration to expand research network may help enhance productivity. Finally, regardless of career stage, boosting 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.

- **Funding**

No funding was received for conducting this study.

- **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.

References

Acton, S.E., Bell, A.J., Toseland, C.P. & Twelvetrees, A. (2019). A survey of new PIs in the UK. *eLife*, 8.

Acuna, D. E., Allesina, S. & Kording, K. P. (2012). Predicting scientific success. *Nature*, 489, 201-202.

Alonso, S., Cabrerizo, F. J., Herrera-Viedma, E. & Herrera, F. (2009). h-Index: A review focused in its variants, computation and standardization for different scientific fields. *Journal of informetrics*, 3, 273-289.

Bates, D., Maechler, M., Bolker, B. & Walker, S. (2015). *Fitting linear mixed-effects models using lme4*. *R package version*.

Bolker, B. M., Brooks, M. E., Clark, C. J., Geange, S. W., Poulsen, J. R., Stevens, M. H. H., & White, J. S. S. (2009). Generalized linear mixed models: a practical guide for ecology and evolution. *Trends in ecology & evolution*, *24*, 127-135.

Bornmann, L. & Daniel, H. D. (2007). What do we know about the h index?. *Journal of the American Society for Information Science and technology*, 58, 1381-1385.

Brischoux, F. & Angelier, F. (2015). Academia's never-ending selection for productivity. *Scientometrics*, 103, 333–336.

Chen, N. (2021). "Why should a 'foreigner' be better than me?": preferential practices in junior academic faculty recruitment among mainland Chinese universities. *Tertiary Education and Management*, 1–25.

Cyranoski, D., Gilbert, N., Ledford, H., Nayar, A. & Yahia, M. (2011). Education: The PhD factory. *Nature*, 472, 276–279.

Danell, R. (2011). Can the quality of scientific work be predicted using information on the author's track record?. *Journal of the American Society for Information Science and Technology*, 62, 50-60.

Fox J. & Weisberg, S. (2019). An R Companion to Applied Regression, 3rd edn. Sage, Thousand Oaks CA.

Garfield, E. (1996). What Is The Primordial Reference For The Phrase "Publish Or Perish"? *The Scientist*, 10, 11.

Ghaffarzadegan, N., Hawley, J., Larson, R. & Xue, Y. (2015). A Note on PhD Population Growth in Biomedical Sciences. *Systems Research and Behavioral Science*, 32, 402–405.

Glänzel, W. (2006). On the h-index - A mathematical approach to a new measure of publication activity and citation impact. *Scientometrics 2006 67:2*, 67, 315–321.

Hirsch, J.E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences*, 102, 16569–16572.

Hsu, G.-C., Lin, W.-J. & Sun, S.-J. Increased academic performance and prolonged career duration among Taiwanese academic faculty in ecology and evolutionary biology. *bioRxiv*, doi: https://doi.org/10.1101/2022.01.31.478501.

Larson, R.C., Ghaffarzadegan, N. & Xue, Y. (2014). Too many PhD graduates or too few academic job openings: The basic reproductive number R0 in academia. *Systems Research and Behavioral Science*, 31, 745–750.

Laurance, W.F., Useche, D.C., Laurance, S.G. & Bradshaw, C.J.A. (2013). Predicting Publication Success for Biologists. *BioScience*, 63, 817–823.

Lenth, R. v. (2021). emmeans: Estimated marginal means, aka least-squares means. R package version 1.7.1. *R Foundation for Statistical Computing*.

Lindahl, J. (2018). Predicting research excellence at the individual level: The importance of publication rate, top journal publications, and top 10% publications in the case of early career mathematicians. *Journal of Informetrics*, 12, 518-533.

Martín-Martín, A., Orduna-Malea, E., Thelwall, M. & López-Cózar, E. D. (2018). Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. *Journal of informetrics*, 12, 1160-1177.

Martín-Martín, A., Thelwall, M., Orduna-Malea, E. & Delgado López-Cózar, E. (2021). Google Scholar, Microsoft Academic, Scopus, Dimensions, Web of Science, and

OpenCitations' COCI: a multidisciplinary comparison of coverage via citations. *Scientometrics*, 126, 871-906.

National Science Foundation. (2018). *Science and Engineering Indicators*. *NSB-2018-1*. Available at: https://www.nsf.gov/statistics/seind/. Last accessed 6 February 2022.

Pauly, D. & Stergiou, K.I. (2005). Equivalence of results from two citation analyses: Thomson ISI's Citation Index and Google's Scholar service. *undefined*, 5, 33–35.

R Development Core Team. (2022). R: A language and environment for statistical computing. *R Foundation for Statistical Computing*.

Rawat, S. & Meena, S. (2014). Publish or perish: Where are we heading? *Journal of Research in Medical Sciences : The Official Journal of Isfahan University of Medical Sciences*, 19, 87.

Ryan Haley, M. (2012). Rank variability of the Publish or Perish metrics for economics and finance journals. *http://dx.doi.org/10.1080/13504851.2012.697115*, 20, 830–836.

Schillebeeckx, M., Maricque, B. & Lewis, C. (2013). The missing piece to changing the university culture. *Nature Biotechnology 2013 31:10*, 31, 938–941.

Shin, J.C. & Kehm, B.M. (2013). Institutionalization of world-class university in global competition. *Institutionalization of World-Class University in Global Competition*, 1–301.

Swihart, R.K., Sundaram, M., Höök, T.O. & Dewoody, J.A. (2016). Factors affecting scholarly performance by wildlife and fisheries faculty. *The Journal of Wildlife Management*, 80, 563–572.

Symonds, M.R.E., Gemmell, N.J., Braisher, T.L., Gorringe, K.L. & Elgar, M.A. (2006). Gender Differences in Publication Output: Towards an Unbiased Metric of Research Performance. *PLOS ONE*, 1, e127.

van Dijk, D., Manor, O. & Carey, L.B. (2014). Publication metrics and success on the academic job market. *Current biology : CB*, 24.

Warren, J.R. (2019). How much do you have to publish to get a job in a top sociology department? Or to get tenure? Trends over a generation. *Sociological Science*, 6, 172–196.

Witteman, H.O., Hendricks, M., Straus, S. & Tannenbaum, C. (2019). Are gender gaps due to evaluations of the applicant or the science? A natural experiment at a national funding agency. *The Lancet*, 393, 531–540.

Xue, Y. & Larson, R.C. (2015). STEM crisis or STEM surplus? Yes and yes. *Monthly labor review*, 2015.

Tables and Figures

Table 1. Results of the GLMMs/LMMs (type II sum of squares) 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	0.0401	0.0006	0.0302	0.0494	4658.02	1	< 0.001
			PhD university origin (Taiwan)	-0.0163	0.0890	-0.1862	0.1527	0.03	1	0.855
			PhD university ranking	0.0001	0.0001	-0.0003	0.0003	0.13	1	0.721
			Gender (Male)	0.4311	0.1094	0.2107	0.6590	15.52	1	< 0.001
Model 2. Academic performance (promotion)	58	"Before" h-index (promotion)	Year of promotion	0.0048	0.0007	-0.0086	0.0184	47.33	1	< 0.001
			PhD university origin (Taiwan)	-0.1594	0.1138	-0.3788	0.0504	1.96	1	0.161
			PhD university ranking	0.0001	0.0002	-0.0004	0.0003	0.00	1	0.979
			Gender (Male)	-0.0584	0.1365	-0.2724	0.1815	0.18	1	0.669
Model 3. Career duration (recruitment)	133	Duration before recruitment	"Before" h-index (recruitment)	0.0193	0.0134	-0.0085	0.0428	2.08	1	0.149
			Year of recruitment	0.0377	0.0064	0.0265	0.0504	35.00	1	< 0.001
			PhD university origin (Taiwan)	0.1759	0.1009	-0.0200	0.3671	3.04	1	0.081
			PhD university ranking	-0.0003	0.0002	-0.0006	0.0001	2.21	1	0.137

			Gender (Male)	-0.0744	0.1198	-0.2985	0.1820	0.39	1	0.535
Model 4. Career duration (promotion)	55	Duration before promotion	"Before" h-index (promotion)	-0.0105	0.0109	-0.0316	0.0107	0.92	1	0.338
			Year of promotion	0.0145	0.0064	0.0026	0.0281	5.08	1	0.024
			PhD university origin (Taiwan)	0.1248	0.0945	-0.0802	0.3004	1.74	1	0.187
			PhD university ranking	-0.0002	0.0001	-0.0004	0.0001	1.29	1	0.256
			Gender (Male)	-0.1617	0.1064	-0.3655	0.0416	2.31	1	0.129
Model 5. Difference in performance (recruitment)	100	"After" h-index − "Before" h-index (recruitment)	Year of recruitment	-0.1866	0.0476	-0.2811	-0.0974	15.38	1	< 0.001
			PhD university origin (Taiwan)	-0.5712	0.8809	-2.2694	1.2721	0.42	1	0.517
			PhD university ranking	0.0009	0.0015	-0.0020	0.0038	0.38	1	0.537
			Gender (Male)	0.2487	0.9837	-1.7603	2.2468	0.06	1	0.800
Model 6. Difference in performance (promotion)	46	"After" h-index − "Before" h-index (promotion)	Year of promotion	-0.1671	0.0972	-0.3745	0.0291	2.96	1	0.086
			PhD university origin (Taiwan)	-2.1577	1.1561	-4.4676	-0.0270	3.48	1	0.062
			PhD university ranking	0.0013	0.0018	-0.0024	0.0052	0.51	1	0.474
			Gender (Male)	1.1835	1.3168	-1.3557	3.9062	0.81	1	0.369

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 variations in academic performance and career duration before recruitment and promotion. Each point represents an individual PI; solid lines represent significant relationships (*P* values are derived 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 and PhD university origin. Each point represents an individual PI; solid/dashed line represents significant/non-significant relationship (*P* values are derived from the LMMs); shaded area indicate 95% confidence intervals.

Figure 1.

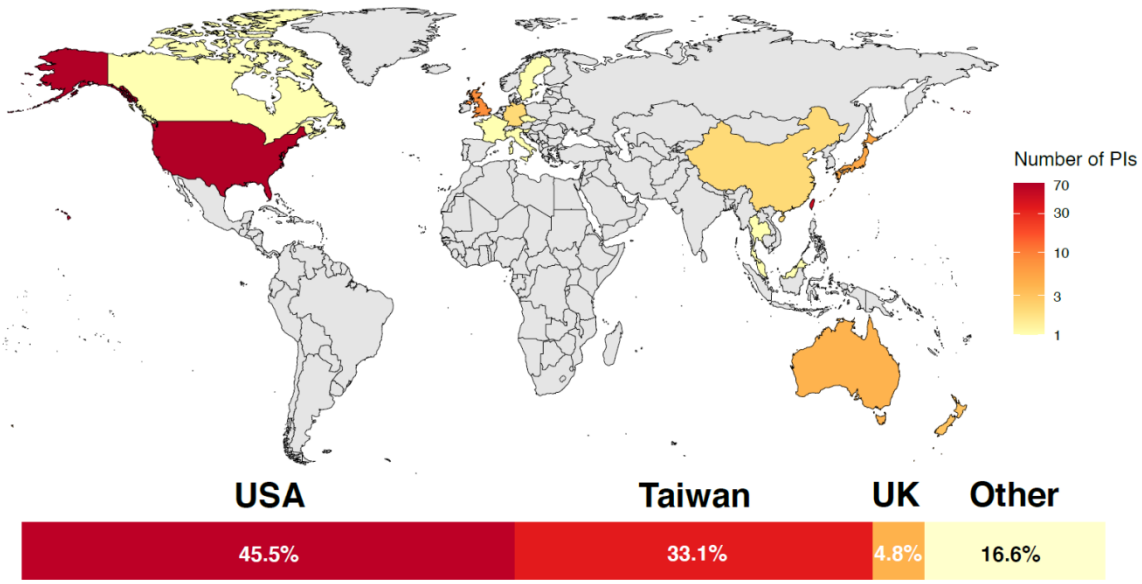


Figure 2.

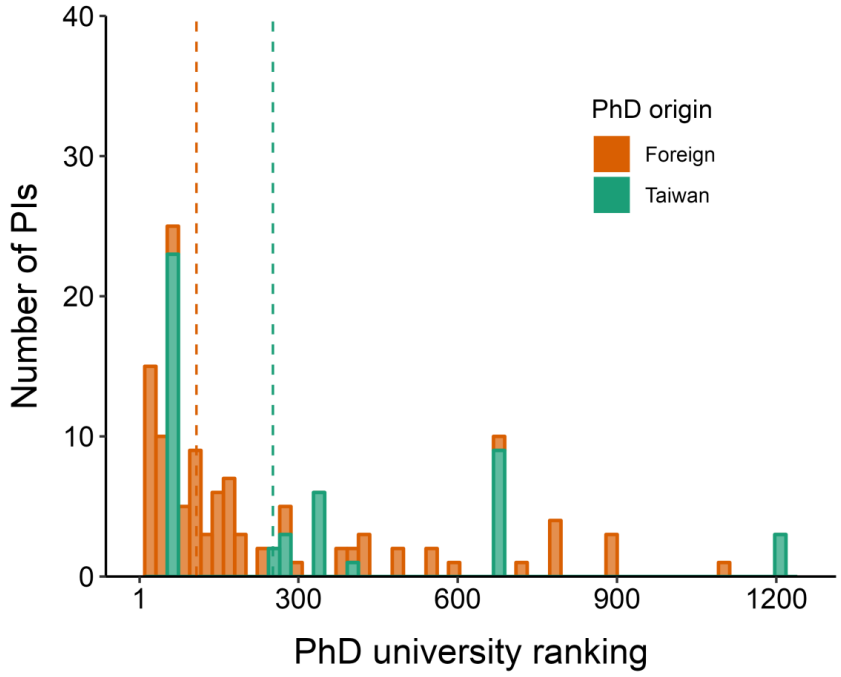

PhD origin
Foreign
Taiwan
Number of PIs
PhD university ranking
0
10
20
30
40
1
300
600
900
1200

Figure 3.

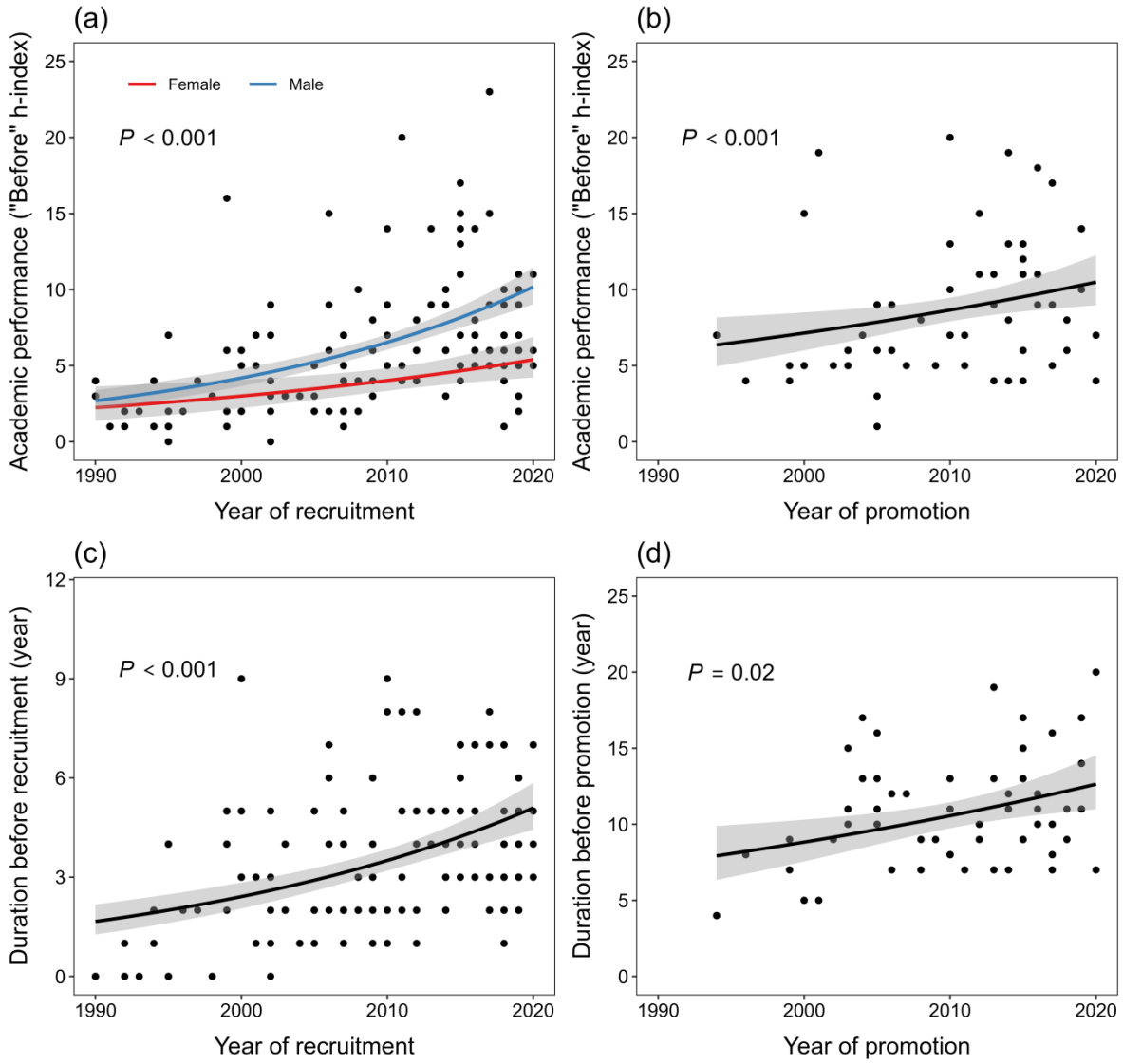
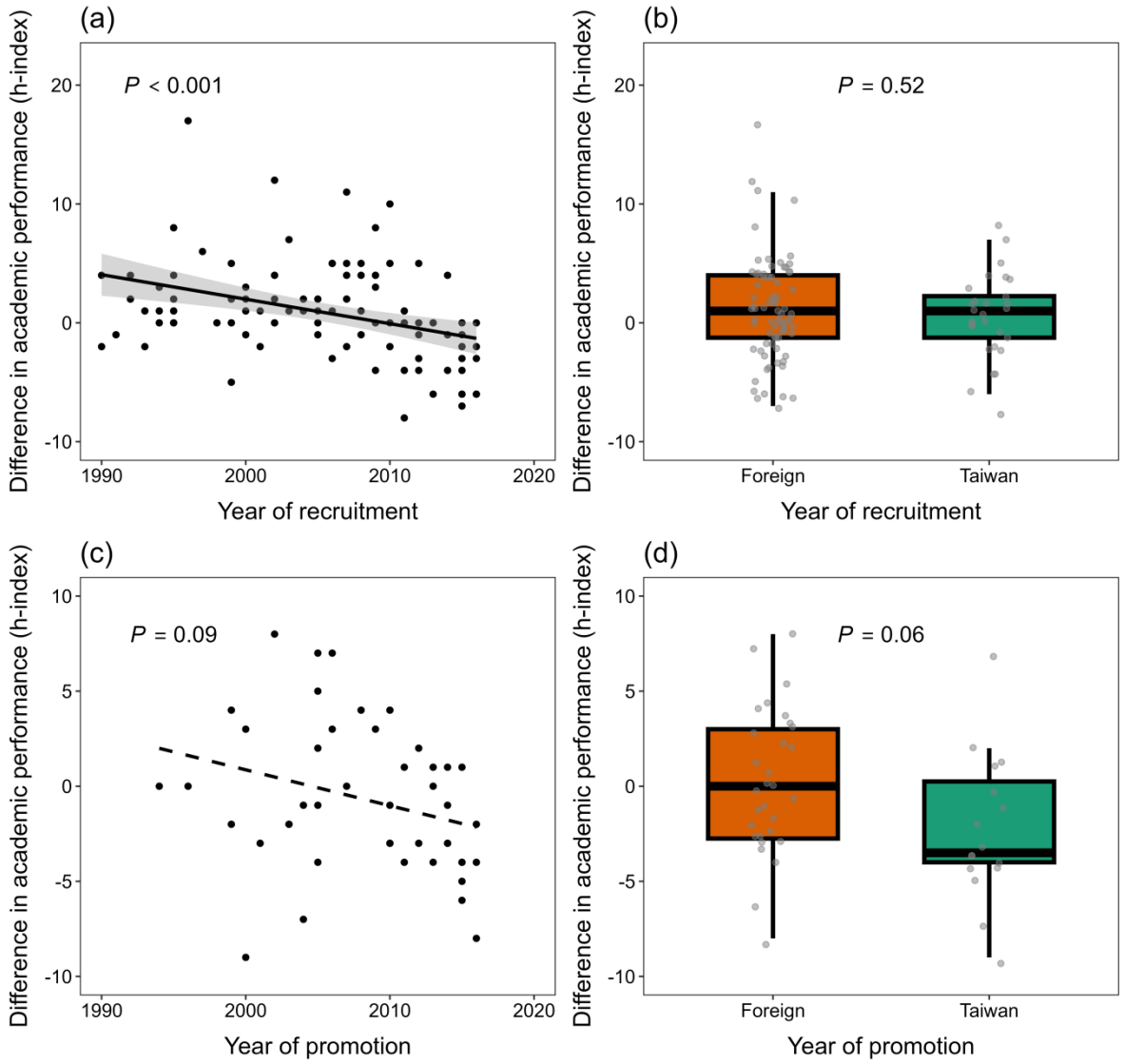

(a)
Female
Male
P < 0.001
Academic performance ("Before" h-index)
Year of recruitment
(b)
P < 0.001
Academic performance ("Before" h-index)
Year of promotion
(c)
P < 0.001
Duration before recruitment (year)
Year of recruitment
(d)
P = 0.02
Duration before promotion (year)
Year of promotion

Figure 4.


(a)
P < 0.001
Difference in academic performance (h-index)
Year of recruitment
(b)
P = 0.52
Foreign
Taiwan
Year of recruitment
(c)
P = 0.09
Year of promotion
(d)
P = 0.06
Foreign
Taiwan
Year of promotion