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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 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 increased academic performance 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: February 17, 2023 Manuscript Number: SCIM-D-22-00945R2 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. 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 the introduction section to include a more extensive review of the current state the research field. •Provided a more detailed description of data collection procedure in the methods section. •Checked for overdispersion of the Poisson models in the statistical analyses and updated the methods, Table 1, and Figure 3a. The figures demonstrating the assumptions of equal variance and normality for all six models in our analyses can be found in the attachment to manuscript. 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): Comment 1 > The authors have responded all the suggestions and added some paragraphs which make this article more complete and readable. Response > Thanks for the positive comments. Reviewer 2's Comments to the Author(s): The authors have made some changes and improvements to the manuscript. However, there are still many unresolved issues and the added information have also revealed new questions and issues. Below is my questions and comments. Hopefully they will help the authors to improve the manuscript. Comment 1 > I recommended that the authors include a more extensive, accurate and nuanced summary of the state the research the authors are aiming to make a contribution to. This is not fully answered in the revised manuscript. The authors have added some of the references I suggested in a sentence but that is not enough to cover the field. Response > We have done a more thorough literature review of the research field and revised the relevant paragraphs in the introduction section: (1) Academic performance (Line 81-94) "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." (2) PhD degree (Line 96-107) "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."

(3) Gender (Line 109-119)

"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."

Comment 2 > The description of the data collection with the publish or perish software is better in the revised manuscript. However, some questions remain: (1) At row 155, the authors write: "We also cross-referenced the results item with the updated curriculum vitae online to ensure the accuracy of search results". How was the accuracy of the search results? And did the authors correct the bibliometric data when mis-matches etcetera was identified? (2) The authors definition of a PI the field of ecology and evolutionary biology is not clearly stated. The selection seems to be based on affiliation. However, the field the authors are investigating is not clearly defined. The readers of Scientometrics may not have deep knowledge of this field. Therefore, I recommend the authors to provide a concise section where the field of ecology and evolutionary biology is defined and described in terms of relevant characteristics, e.g., formal scientific communication, publication praxis, collaboration, interdisciplinarity, etcetera. As of now several questions arise when I read the data collection section. Are the different departments the authors refer to sub-fields in the field of inquiry? Is publication praxis and citation rates similar in these sub-fields? Did all PIs publish in the field of ecology and evolutionary biology during their whole career or did some publish in other fields earlier in their careers and then transitioned to this field? Did all PIs do their PhDs in this field?

Response > Thanks for the comments on the data collection and PIs' PhD backgrounds. Below are our responses to the questions raised:

(1) What is the accuracy of the search results: In most cases, the results from the search engine were accurate. There were occasional duplicates (multiple occurrences of the same publication) in the search results, and we manually removed them before calculating the h-index.

(2) How is the field of ecology and evolutionary biology defined: 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, organism behavior, species abundance and distribution, species interactions, community and ecosystem dynamics, biodiversity and conservation.

To identify the PIs for our analysis, we first generated a list of biology-related departments/divisions at the eight top-ranked universities/institution in Taiwan, which yielded a total of 81 departments/divisions. We then went through these 81 departments/divisions and excluded those that focus primarily on biomedical sciences, leaving 33 departments/divisions after this filtering. For each of these 33 departments/divisions, we visited the website, recorded PIs whose areas of research and publications fell within our definition of ecology and evolutionary biology, and collected the necessary data (year of recruitment/promotion, h-index, gender, PhD education, etc.) for further analysis.

We have now included a more detailed description of the data collection procedure in the methods section (Line 140-168):
“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.”
(3) Are the different departments the sub-fields in ecology and evolutionary biology: As mentioned above, the main criterion for selecting PIs in our study is the areas of research and publications. Therefore, even though these PIs sit in different departments, this does not necessarily mean that they belong to different sub-fields (and we did not define sub-fields in our study).
(4) Did all PIs publish in the field of ecology and evolutionary biology: Yes. Because we selected our PIs based on their areas of publications, they all publish in this field. Otherwise, they would not have been included in our data set.
(5) Did all PIs do their PhDs in ecology and evolutionary biology: Most PIs in our study did their PhDs in ecology and evolutionary biology, even though the degree titles might not directly be Ecology and Evolutionary Biology (e.g., PhD in Biology or Zoology). Some PIs obtained their PhDs in other related fields (e.g., forestry, agricultural sciences, botany, and fishery), but their publications fell within our definition of the field and thus were included in our analysis.

Comment 3 > The issue of not using a normalized bibliometric indicator is unfortunately only partly resolved since the authors choose to continue with the h-index. First, the authors claim that normalization by field is not necessary since all PIs was faculty at one of 8 HEIs at time of data collection, but they have not provided any proper arguments or evidence in their manuscript to back this claim. Normalization might be relevant also at the sub-field level (Van Eck et al., 2013). Second, the authors write "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 variation in h-index among the two publication types were reduced". I do not understand this reasoning because it is not in line with the logic behind normalizing for document type in the scientometric literature. Are the publication rates similar for authors that publish more chapters and authors that publish more articles? Are citation rates similar for chapters and articles in the field they are investigating and in the sample? I recommend that the authors clarify their reasoning here and provide good references and arguments for how this works.
Response > Thanks for pointing out the issue regarding the variations in h-index at the sub-field level. In Van Eck et al. (2013), there were substantial differences in citation practices among areas of basic and diagnostic research and clinical intervention research in medical sciences. On the other hand, the majority of publications in the field of ecology and evolutionary biology are basic research. Moreover, Van Eck et al.

(2013) compared the citation patterns among three WoS subjects Cardiac & cardiovascular systems, Clinical neurology, and Surgery within the medical field (in other words, these three subjects were the “sub-fields” in their study), whereas our study focuses mainly on a single WoS subject Ecology (which is equivalent to a sub-field in Van Eck et al. [2013]). Therefore, the within-field differences should be relatively lower compared to those revealed by Van Eck et al. (2013). Nonetheless, we do acknowledge that within-field citation variations may still exist in our study and we have added this potential caveat to the discussion section (Line 390-392):
“Finally, our analyses were based on PIs in ecology and evolutionary biology, within which variations in publication performance and citation patterns may exist.”
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.

Comment 4 > The authors have included a section about google scholar but they have not provided convincing arguments. The argument of free access is irrelevant in this context. The argument that the lack of good metadata in google scholar does not matter for the authors study since they are not using it, is not really true. If the authors had used a citation database with good metadata etcetera, e.g., Scopus, it would have been easier to use a normalized bibliometric indicator as the dependent variable which would have strengthened the study.
Response > The critical bibliometric indexes for our analyses are the number of publications, annual citations, and year of publication. These are readily available on Google Scholar Profiles. On the other hand, the metadata for researchers’ publications concern mainly DOI, affiliation data, funding information, etc., which are not directly relevant to our study regardless of which search engine is used. In fact, as mentioned in our previous response, studies have shown that Google Scholar has a wider coverage compared to WoS or Scopus, and if metadata are not of substantial importance, Google Scholar might be preferable.
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.”

References:
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.

Comment 5 > The authors have now included information about missingness in the manuscript. At row 486, Tables and figures, the size of the sample used for each model is presented. In the model with the lowest number of missing values the missingness is 7.6 % (model 1). In model 2, 4, and 6 is very high. In model 2 the sample size is 58 out of 145, i.e, 60% missing values, in model 4 there are 62% missing values, and in model 6 there are 68% missing values. Listwise deletion might be a reasonable method to handle missingness below 5% (Graham, 2009) depending on the mechanism for the missingness. When the missingness in the range presented by the authors the missingness needs to be addressed with some more advanced method than list wise deletion to handle the missingness, e.g., multiple imputation with chained equations. However, given the small sample in combination with a missingness of this magnitude, I doubt that the authors can provide a convincing solution other than collecting more data. How can we be sure that the authors results are not biased by the large amount of missingness?
Response > Thanks for the suggestion and the reference for handling missing data. In fact, the missing entries in our data set were not true missingness due to incomplete records. Rather, these missing entries simply did not exist because not all PIs in our data set were full professors. For assistant and associate professors, there would be no data during the promotion phase. This is why Model 2, 4, and 6 had much lower sample sizes compared to Model 1, 3, and 5.

Because of the nature of the missing entries, it may not be suitable to conduct multiple imputation for our data set: the promotion data for PIs who were not full professors cannot be simply modeled/predicted by the full professors. Moreover, these missing entries should not introduce biases into our analysis because they were not truly missing but indeed non-existent. That said, we acknowledge that the sample sizes for Model 2, 4, and 6 might not be satisfactory. Nonetheless, given that the field of ecological and evolutionary biology in Taiwan is relatively small, we feel that our results could still provide useful information for this field despite the relatively low sample sizes (also see our response to Comment 6 regarding the representativeness of the sample).

Comment 6 > I do not think the authors conclusions are supported by the data. Given the small sample size and the descriptive statistics I believe the authors need to show that their sample is representative by (1) defining a population; (2) Compare the variables in the sample with the equivalent variables in the population (e.g., how the proportion of men and women in the sample compare with the proportion of men and women in the population; How does the percentages of full, associate, and assistant professors compare with the population, etcetera). The authors should also show that the 8 Higher Education Institutions (HEI) are representative and how the PIs are distributed over the HEIs and compare the share of PIs in the HEIs in the sample with the share in the population. How many HEIs are there in the sampling frame? Why have the authors only sampled from top ranked HEIs? How does that comply with the representativity of the sample?
Response > Following the same criteria for selecting the 145 PIs from the eight universities/institution in our study, we did a survey of all universities/institutions in Taiwan and identified additional 81 PIs in the field of ecology and evolutionary biology from 11 public universities. This gives a total of 226 PIs as the “population” underlying our study. We then examined whether the PIs in our study are representative of this population by comparing the academic rank and gender composition of our PI sample with that of the entire PI population using a Chi-square test:
(1) Academic rank composition ($\chi2 = 1.26$, df = 2, $P = 0.53$)

	Assistant professor	Associate professor	Full professor
PIs in our study	44 (30.3%)	36 (24.8%)	65 (44.8%)
Entire PI population	68 (30.1%)	65 (28.8%)	93 (41.2%)

(2) Gender composition ($\chi2 = 0.64$, df = 1, $P = 0.42$)

	Male	Female
PIs in our study	112 (77.2%)	33 (22.8%)
Entire PI population	168 (74.3%)	58 (25.7%)

The test results show that the academic rank and gender composition of the PIs in our study did not deviate from that of the entire population, confirming the representativeness of our sample.
The table below shows the distribution of 145 PIs among the eight universities/institution in our study:

University/institution	Number of PIs
National Taiwan University	47
National Chung Hsing University	28
Academia Sinica	26
National Sun Yat-sen University	16
National Taiwan Normal University	13
National Cheng Kung University	9
National Tsing Hua University	5
National Yang Ming Chiao Tung University	1

A high proportion of the PIs came from National Taiwan University, National Chung Hsing University, and Academia Sinica, three of the largest research entities in the field of biology (including ecology and evolutionary biology) in Taiwan. On the other hand, there were only a few PIs from National Tsing Hua University and National Yang Ming Chiao Tung University because ecology and evolutionary biology is not a main research area in their biology departments.
We included PIs only from the eight top-ranked universities/institution in Taiwan for the following reasons:
(1) The research environment and funding resources differ between higher-ranked and lower-ranked universities/institutions (generally having fewer funding opportunities).

Such inherent differences could affect the research outputs of PIs, and therefore including PIs from lower-ranked universities/institutions might introduce biases into our results.
(2) Most job applicants will set higher-ranked universities/institutions as their top priorities. Thus, from the applicants' perspective, it would be more relevant to focus on the patterns in these universities/institutions.
Moreover, the potential concern that the PIs from these eight universities/institution might not be representative of the entire PI population in this field in Taiwan is partially eased, as suggested by the above comparisons.

Comment 7 > At row 208 I cannot see any regression diagnostics for the poisson regressions. Why did the authors choose poisson over negative binomial regression? Have the authors tested the poisson models for over dispersion?
Response > We did check the assumptions of equal variance and normality for all six models in our analyses in our previous revision. However, there seemed to be a mistake in the online submission system and the figures for model diagnostics in our response document were lost. We provided them again below. Overall, there was no severe violation of the assumptions. The residuals in Model 5 seemed 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). (The diagnostic plots below were generated using the R package "performance".)
Model 1

Model 2

Model 3

Model 4

Model 5

Model 6

We also checked for overdispersion in our Poisson models (Model 1. 2, 3, and 4) using the function "check_overdispersion()" from the R package "performance". The test results showed that Model 1 was overdispersed, and therefore we refit the model using a negative binomial distribution and a log link function.

	Dispersion ratio	$\chi2$	df	P
Model 1	1.57	199.59	130	< 0.001
Model 2	1.26	64.01	51	0.10
Model 3	1.20	149.58	125	0.07
Model 4	0.70	32.98	47	0.94

The parts in the manuscript relevant to Model 1 were updated accordingly:
(1) Methods:
"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 ($\chi2$ = 199.59, df = 130, P < 0.001); Model 2 was fitted with a Poisson error distribution and a log link function as no significant overdispersion was detected ($\chi2$ = 64.01, df = 51, P = 0.10)." (Line 234-238)
"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: $\chi2$ = 149.58, df = 125, P = 0.07; Model 4: $\chi2$ = 32.98, df = 47, P = 0.94)." (Line 245-248)
(2) The statistical results for Model 1 in Table 1.
(3) Figure 3a.

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. References suggested by Reviewer 2 Graham, J. W. (2009). Missing data analysis: Making it work in the real world. Annual review of psychology, 60, 549-576. Van Eck, N. J., Waltman, L., van Raan, A. F., Klautz, R. J., & Peul, W. C. (2013). Citation analysis may severely underestimate the impact of clinical research as compared to basic research. PloS one, 8(4), e62395.

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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 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 increased academic performance 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 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 papers and book chapters regardless of authorship (PhD theses and conference presentations were excluded). 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 = 199.59, *df* =

130, 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 = 64.01, df = 51, P = 0.10).

(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 = 149.58, df = 125, P = 0.07; Model 4: χ^2 = 32.98, df = 47, P = 0.94).

(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 16 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. 0.005; 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 (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 candidates 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 PI 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 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 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	0.0429	0.0004	0.0302	0.0494	4658.02	1	< 0.001
			PhD university origin (Taiwan)	-0.0606	0.1097	-0.1862	0.1527	0.03	1	0.855
			PhD university ranking	0.0001	0.0002	-0.0003	0.0003	0.13	1	0.722
			Gender (Male)	0.4510	0.1326	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 minus “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 minus “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 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.

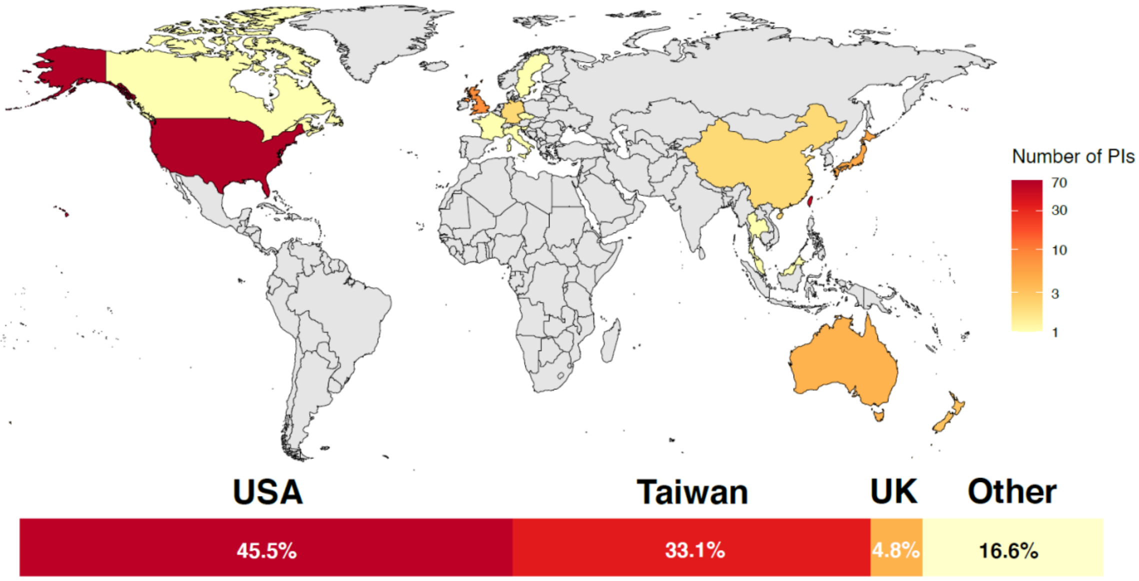
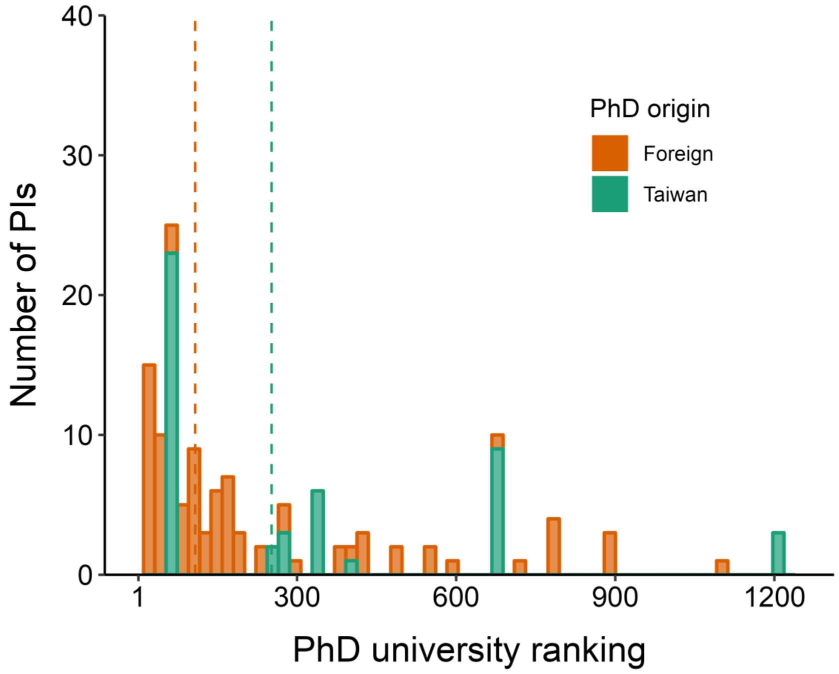


Figure 2.



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

Figure 3.

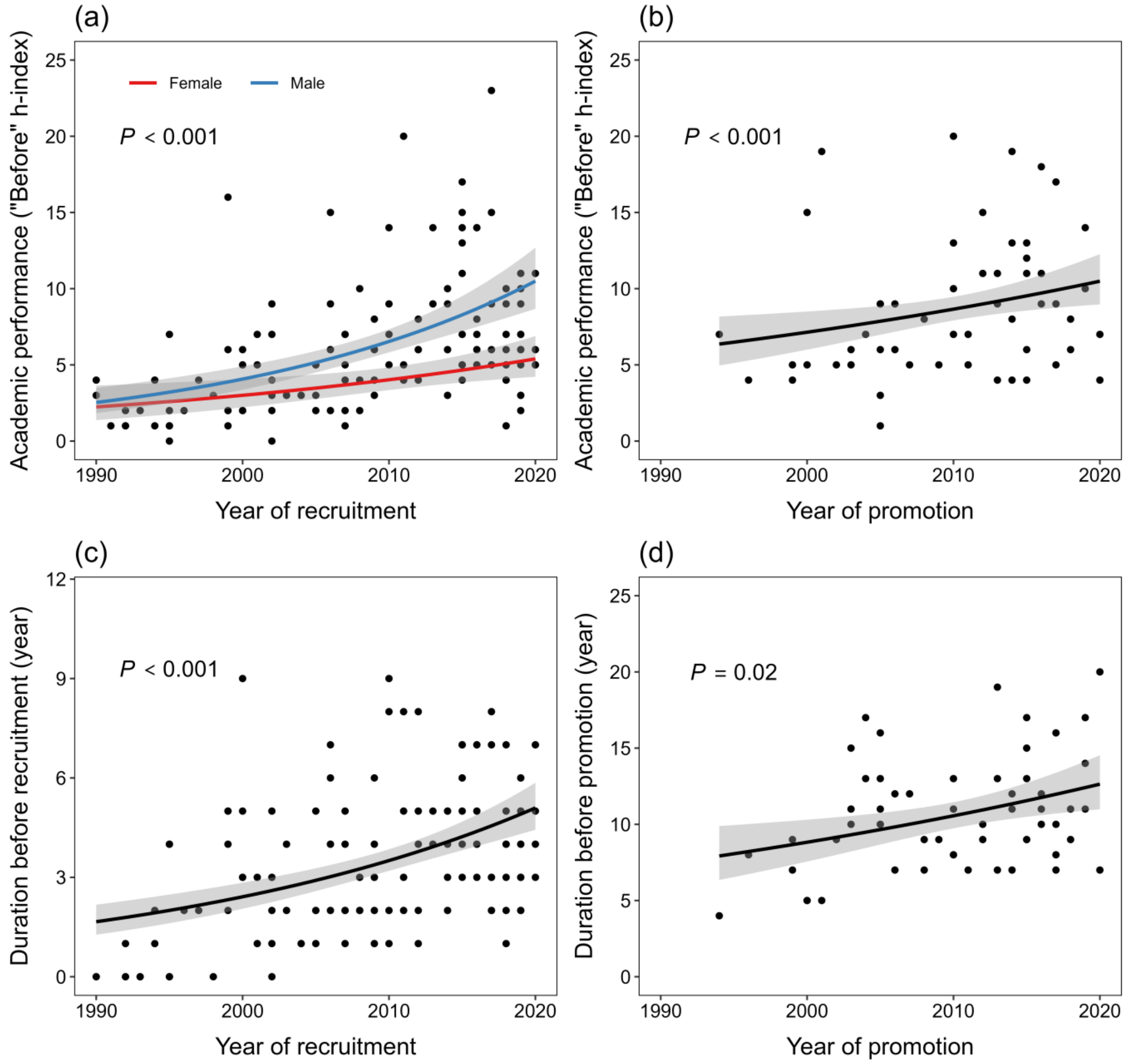
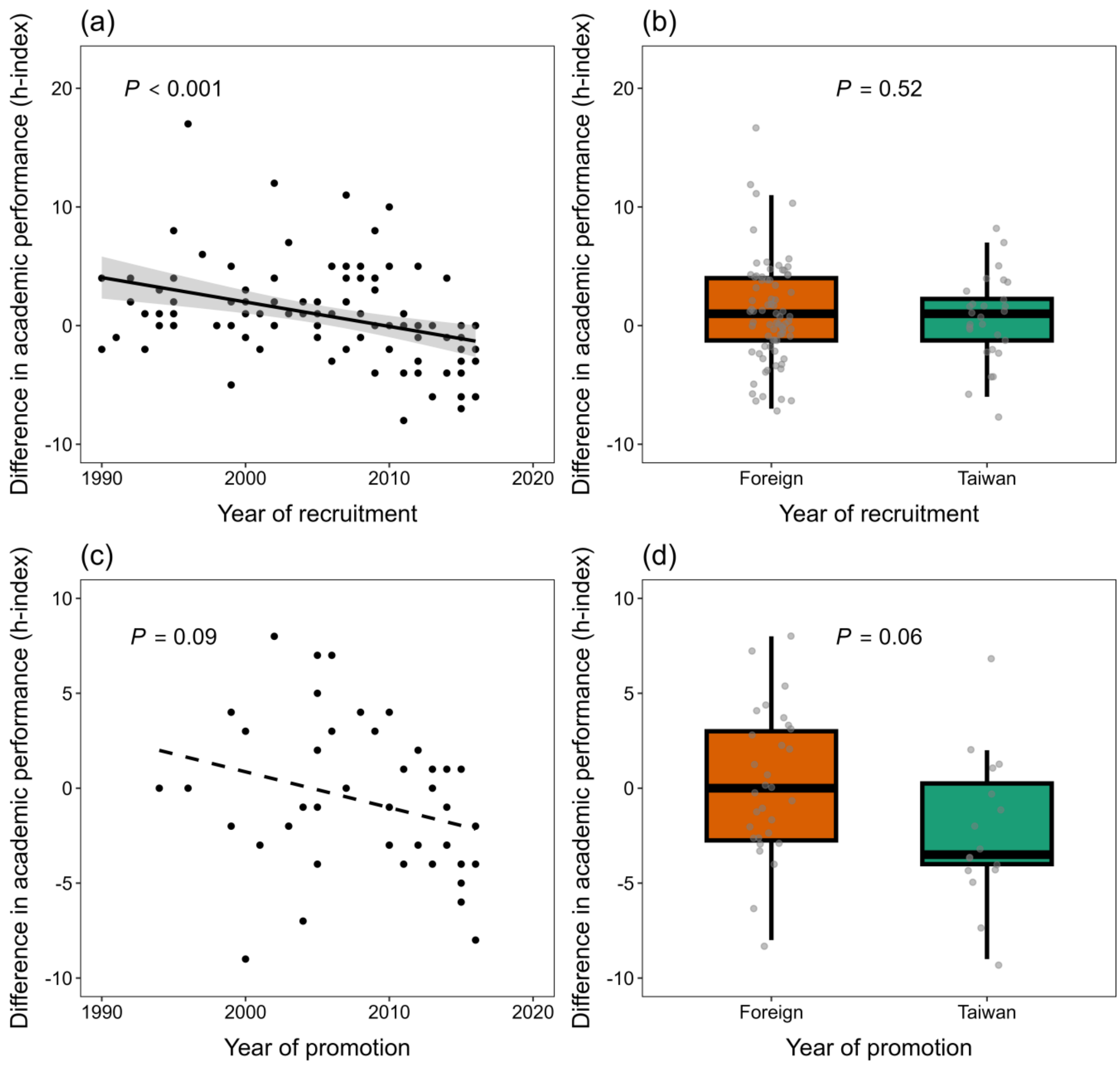

(a)
Female
Male
P < 0.001
Academic performance ("Before" h-index)
Year of recruitment
(b)
P < 0.001
Academic performance ("Before" h-index)
Year of promotion
(c)
P < 0.001
Duration before recruitment (year)
Year of recruitment
(d)
P = 0.02
Duration before promotion (year)
Year of promotion

Figure 4.


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

Response to reviewers' comments

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