sustainability

MDPI

Article

Does Interdisciplinary Research Lead to Higher Faculty Performance? Evidence from an Accelerated Research University in China

Li Yu [1,*,†], Yue Yan [2,†] and Mingjun Li [3]

[1] Center for Higher Education Research, Southern University of Science and Technology, Shenzhen 518055, China
[2] Business School of Zhangjiagang Campus, Jiangsu University of Science and Technology, Zhenjiang 215600, China
[3] Institute of Public Policy, South China University of Technology, Guangzhou 510641, China
* Correspondence: ppyul@scut.edu.cn
† These authors have contributed equally to this work and share first authorship.

Abstract: The current trend of building accelerated research universities in China that explore the pursuit of interdisciplinary research (IDR) approach to yield academic excellence and innovation through institutional reforms is aspiring to achieve the Sustainable Development Goals (SDGs). Employing data from faculty Curriculum Vitae and bibliometric records from a pilot accelerated research university in China, this study provides a case study to empirically quantify the impact of interdisciplinary research on 490 faculty's performance, including research productivity, impact, and prestige. Results show that faculty involved in interdisciplinary research outperform their non-interdisciplinary counterparts in terms of research productivity, impact, and prestige. The degree of interdisciplinary as measured by subject categories is positively associated with faculty research performance. However, there are heterogeneous effects across faculty subgroups since faculty in applied-oriented disciplines reap more benefits while young faculty may suffer. Additionally, this study finds that faculty individual interdisciplinary research behavior can be affected by school-level concentration and dispersion of the degree of interdisciplinarity, which suggests the existence of peer effects.

Keywords: interdisciplinary research (IDR); accelerated research university; research collaboration; faculty performance

Citation: Yu, L.; Yan, Y.; Li, M. Does Interdisciplinary Research Lead to Higher Faculty Performance? Evidence from an Accelerated Research University in China. *Sustainability* **2022**, *14*, 13977. https://doi.org/10.3390/su142113977

Academic Editor: Gazi Mahabubul Alam

Received: 23 August 2022
Accepted: 24 October 2022
Published: 27 October 2022

1. Introduction

UN Sustainable Development Goals (SDGs) are used to guide the global development work from 2015–2030 to better solve global problems, such as poverty eradication, inequality reduction, and climate change and impacts. Within a single discipline, it is impossible to solve the practical problem [1]. Many sustainability-related topics, including sustainable city system study [2], sustainable regulated river management [3], sustainable education, environments, and business management [4], frequently adopt an interdisciplinary research approach because of complexities, ambiguities, and dynamic exchanges of these topics [5]. In addition, scientific research is driven by people. Some of the most influential scientists driving SDG research are conducting interdisciplinary research scattered across disciplines.

According to SDGs, the ninth item specifically indicates that industry, innovation, infrastructure, and investment in infrastructure and innovation are crucial drivers of economic growth and development. In addition, the role of Education for Sustainable Development (ESD) for SDGs is highlighted in the fourth item [6], and universities are at the forefront of driving ESD and are always innovating [7]. With over half the world population now living in cities, mass transport and renewable energy are becoming ever more

important due to the growth of new industries and information and communication technologies. Technological progress is also key to finding lasting solutions to both economic and environmental challenges, such as providing new jobs and promoting energy efficiency. Promoting sustainable industries and investing in scientific research and innovation are all important ways to facilitate sustainable development. Scientific excellence plays a key role in introducing and promoting innovation and new technologies, and innovation and technological progress are essential to find lasting solutions to global challenges and can unleash dynamic and competitive economic forces that ensure sustainable development. Given the assumption underlying the policies is that interdisciplinary research crosses the boundaries between different fields of study to introduce unconventional, innovative approaches and scientific inventions, it is crucial to foster sustainable innovation and entrepreneurship through interdisciplinary research.

In the view of scientists, policymakers, and fund providers, interdisciplinary research is of great significance and plays a great role in generating "breakthrough" research results. There are two main advantages to support interdisciplinary research compared to standard disciplinary research. First, it has been argued that interdisciplinary research can not only solve the issues and difficulties brought by the complexity of research, but also mobilize the knowledge stock of each involved academic field. Second, the major discoveries and innovations in modern science often depend on the knowledge exchange and mutual penetration of multiple disciplines. The intersection of different disciplines is often the growth point and scientific frontier of new disciplines and is most likely to produce major scientific discoveries. Since the mid-1980s, more and more papers in the international academic circle began to cite papers outside their field. The Nobel Prize winners were able to discover the impact of interdisciplinarity, such as Shechtman's 1984 paper [8], which had a largely interdisciplinary impact, being cited significantly by papers from physics, engineering, and chemistry (its field of award) [9]. Due to the unique cutting-edge and innovation potential of interdisciplinary research, governments and funding institutions around the world have paid great attention to and supported interdisciplinary science projects in recent years. For example, it has increasingly become an important dimension taken into account in public funding processes both in the EU framework and US NSF funding programs. In 2020, the National Natural Science Foundation of China (NSFC) established the department of interdisciplinary science to plan and guide research at the scientific frontier and interdisciplinary fields to meet the major national strategic needs.

One common trend and important development strategy of world-class universities is promoting interdisciplinary research. In recent years, with the implementation of the "first-class university and first-class discipline" construction of colleges and universities in China, more attention has been paid to interdisciplinary research at the national policy level. The policies on further promoting the construction of world-class universities and first-class disciplines put forward that colleges and universities should optimize the layout of disciplines, break the barriers between conventional disciplines, highlight the cross integration and collaborative innovation of disciplines, and vigorously encourage high-quality cooperation across universities, institutions, and disciplines. However, the breadth and depth of interdisciplinary research in colleges and universities in China are still very limited and face multiple obstacles and constraints. For a long time, scientific research activities in Chinese universities are mainly carried out within colleges and research organizations that are usually established based on a single discipline. The research fields of these colleges or organizations are highly concentrated, focusing on certain research directions under a single discipline. The colleges and organizations dominated by a single discipline usually fail to carry out interdisciplinary research by themselves since they face strict organizational barriers among disciplines that makes them difficult to make interdisciplinary exchanges and cooperation effectively. Furthermore, these organizational arrangements restrict the integration of multidisciplinary research resources and make it harder for scholars to have a sense of identity and belonging.

2. Institutional Background

Under the national strategies for innovation-driven development, our sampled university (University S) is a newly established accelerated research university that focuses on science, technology and medicine and is supplemented with business and humanities and social science disciplines in China. Since its inception in 2011, University S has always adhered to the development principle of pursuing small and strong, rather than large and comprehensive disciplines. The university focuses on developing basic disciplines such as mathematics, physics, chemistry, and mechanics with its own characteristics and advantages and offers interdisciplinary pedagogy to cultivate well-rounded college graduates with innovative thinking. With rapid development, it achieved outstanding research ratings in the research assessment and was ranked as the top 10 Chinese universities in Times Higher Education's Young University Rankings 2020.

Taking the entirely new University S as a representative of accelerated research universities in China, several pilot reforms were implemented to promote interdisciplinary research: first, it urges colleges to break down the barriers of departments and majors, let prominent scientists worldwide take leading roles, and build joint research teams with cooperation across departments to tackle major scientific problems and core technologies given that a single discipline can barely achieve the goals. The university attracted a number of world-class scientists through international forums and other large-scale international academic conferences to join the academy, exploring a new mode of talent invitation through special exchange and visit funds, and inviting professors on sabbatical leave to establish a close link with universities and laboratories at the frontier science. The university has also strengthened the construction of large teams based on the PI (principal investigator) system in which top scholars are allowed to lead the formation of large teams and gather multidisciplinary researchers to cooperate according to the needs, to solve the problems of self-research and weak adaptation to deal with big technical problems. The PI system is allowed to hire research-track professors and postdocs with funding jointly bore by the research team and university.

Second, the university emphasizes building scientific research platforms and centers that foster interdisciplinary research. Take the Academy for Advanced Interdisciplinary Studies (hereinafter referred to as the Academy) for example, it is committed to promoting the cross integration of frontier science exploration and research to a high degree. Guided by major scientific problems, the academy actively integrates the advantages of different professional disciplines, gathers talents in multiple fields, builds a large-scale shared experimental platform, provides a place for ideological collision, breaks through major scientific and technological problems that are difficult to be solved by a single discipline, and takes this opportunity to explore the mechanism and methods of discipline integration and new growth points, to create a high-end academic ecology. Established in 2016, it is the management organization of the university's cutting-edge cross-scientific research center. By organizing researchers from different disciplines and professional backgrounds to carry out collaborative research, innovate systems, and mechanisms, the Academy focuses on major scientific research directions, crosses discipline boundaries, realize thinking collision and technology sharing among disciplines, and actively promotes the cutting-edge scientific development and advanced technological innovation. In addition, the university has set up joint laboratories with leading enterprises in the local community through the "dual employment system" to strengthen university–industry collaboration and talent cultivation.

Third, University S is carrying out a large-scale faculty evaluation reform to extend the term of evaluation and split the contributions within research teams. For one thing, major scientific research tasks can hardly be completed in two or three years. It may take five to 10 years or more, and it requires multiple teams to work together. Therefore, universities should not adopt the short-term evaluation method for the team of jointly tackling major projects, nor the traditional method of evaluating the department of the team separately. Colleges and universities should strive to guide researchers and research teams to carry out long-term research according to the nature of science. Furthermore, it adopts different

evaluation methods of scientific research achievements with different emphases to build a long-term evaluation mechanism for basic and applied scientific research according to the characteristics of different disciplines. The university does not take the number of articles as the key evaluation standard, but gradually and comprehensively implements the representative work evaluation system. The system focuses on international peer evaluation, academic contribution and academic influence, and transformation of intellectual property achievements. At the same time, University S strives to improve the evaluation methods of research teams, focusing on cooperation in solving major scientific and technological problems and fully recognizing and fairly treating the actual contributions of all team participants.

In conclusion, with continuous support from the government, university S's reforms bring together resources, capital, and enterprises to promote interdisciplinary cooperation, pursue major innovation advancement, and develop a sustainable innovation system highlighting interdisciplinary research. Although these interdisciplinary education reforms and practices seem to be effective, empirical evidence is still rare. Therefore, the following research questions are proposed under the context of accelerated research universities to empirically test whether IDR accelerates research performance at faculty level and its possible mechanisms: does interdisciplinary research lead to higher faculty performance in terms of research productivity, impact, and prestige in accelerated research universities in China? Are there heterogeneous effects of interdisciplinary research among faculty members in such universities? Is there any peer effect of interdisciplinary research? Answering these questions would be the starting point to understand and leverage research accelerated universities' advantages in its research modes across disciplines when increasingly more interdisciplinary research platforms and projects have been launched in China's universities.

3. Literature Review

It is emphasized by the previous study that interdisciplinary connections are fundamental to all future research because the interfaces of the sciences are the most intense [10]. Interdisciplinary research can be roughly divided into two forms: collaboration research and individual interdisciplinary. Collaboration among scientists can be considered a typical form of scientist-scientist interaction [11]. Despite the interdisciplinary by collaborating with authors from different institutions or disciplines, a single author can also make an interdisciplinary study. Some papers categorized as "non-collaborative" were written by highly interdisciplinary individuals, who were not reflected in authorship [12].

Interdisciplinary research can improve researcher performance in many ways. Many observations find that interdisciplinary can increase productivity. At the university level, universities support their interdisciplinary by raising interdisciplinary departments and research centers, this can be seen as the structural commitment to IDR [13]. Such commitment to IDR can improve the interdisciplinary scholarly productivity of institutions [14]. At the individual level, whether interdisciplinary research has greater productivity has been controversial. Karr's [15] study indicates that scientific productivity increases exponentially with a scientist's interdisciplinarity and that of their collaborators. However, in Leahey's [16] statistics, interdisciplinary scientists experience lower productivity. She finds that in the year when scholars do more interdisciplinary work, they publish fewer articles. However, interdisciplinary productivity is influenced by many other factors, such as gender, age, the position of authors, the quality of colleagues' publications, and so on [17–19].

In the academic field, citations can be used as a factor to measure academic impact, because citations can reflect the visibility of the paper in the scientific community [20–22]. At the university level, the scientific publications published by collaborations have positive externalities for all the universities [23]. For scholars, Leahey's [16] study shows that interdisciplinary can increase scholarly visibility, in other words, IDR can increase scholars' impact. Along with the trends over time, higher interdisciplinary publications tend to attract more citations and have higher PLoS usage [24]. Shi et al. [25] used the bibliometric to quantify the effect of interdisciplinary research. They found that authors who cite across

disciplines can garner more citations, which are measured as impact. This result indicated that the cross-fertilization of research has a significant impact on research performance. They also found that in the natural science area, those who draw research outside of their area will have more influence on their study. While in social science, the impact of their research is affected by one's field. Despite two extremes existing, highly collaborative but slightly interdisciplinary and highly interdisciplinary individuals, collaboration positively correlated with interdisciplinarity [11]. In the study of some European countries, the knowledge flows among researchers from different universities are relevant to enhancing the quality of research. The collaborations can improve the effectiveness of research and raise the performance level [26].

In addition, interdisciplinary research can also play a role in higher-level research. Interdisciplinarity will be more relevant and responsive to public needs and concerns [27]. IDR is also good at problem solving. Stirling [28] argues that IDR is more successful at problem solving. Since cognitive diversity can help in hedging against ignorance and accommodating plural perspectives, IDR can be seen as a source of creativity and innovativeness because it challenges established approaches and discovers new areas of research.

Though IDR brings benefits to research performance, it also entails metaphorically costs, such as coordination costs and institutional barriers which are also explained as a disadvantage with an appreciation of the value of interdisciplinary research [29]. In Yegros-Yegros's [30] study, there is an inverted U-shape relationship between IDR and citation impact. The curvilinear relationship indicates that three is an initial positive effect on the citation impact of publications, but higher levels of diversity will have a detrimental effect on the citation impact of publications. One characteristic is that highly disciplinary and highly interdisciplinary articles have a low scientific impact. There might be an optimum of interdisciplinarity [31]. Wang et al. [32] show that the number of citations with a low interdisciplinary degree was greater than that of papers with a high interdisciplinary degree. In other words, there is an "optimal value" between influence and degree of interdisciplinarity. When the interdisciplinary degree reaches a certain value (not the maximum value), the influence of the paper is the greatest.

4. Research Design

4.1. Research Hypothesis

As discussed in the previous section, we argue that although interdisciplinary research is often valued more than single discipline research in theory, there is no simple relationship between interdisciplinary research and research performance at the individual level, and it may be the role of benefit or penalty [16]. Therefore, we examine whether conducting interdisciplinary research affects the number of publications, research impact, and prestige of faculty individuals having by proposing the following hypothesis:

Hypothesis 1a: *Compared with non-interdisciplinary research, interdisciplinary research is associated with higher faculty performance in terms of productivity, impact, and prestige.*

Hypothesis 1b: *The degree of interdisciplinary research/interdisciplinarity is associated with higher faculty performance in terms of productivity, impact, and prestige.*

Faculty's intrinsic individual characteristics may decide whether they involve in IDR and how they behave. Who reaps more benefits from conducting IDR? Bird [33] has done an interdisciplinary interview study on women in academics. In addition to gender, working experiences and research orientation also seem to play roles. Evans [34] emphasizes encouraging young academics into the interdisciplinary field and making them into interdisciplinarians. However, in contrast, young scientists who are exposed to more interdisciplinary topics run the risk of taking longer to establish themselves in their careers [10]. In fact, interdisciplinary work often has an applied orientation [35]. Hence, we postulate:

Hypothesis 2a: *The impact of interdisciplinary research is heterogeneous among faculty members with different working experiences, and young faculty are more likely to be influenced.*

Hypothesis 2b: *The impact of interdisciplinary research is heterogeneous among faculty members with different research orientations, and faculty who engaged in applied-oriented research are more likely to be influenced.*

In fact, interdisciplinary research behavior is an interaction in nature and depends highly on university schools, departments, or centers, which constitute organizational pools of scientific and technological human capital based on the skills, knowledge, abilities, and resources of their participants. Carayol [18] argued that the university and laboratory are the loci of interactions, therefore, it is important to combine individual and collective determinants to explain individual research productivity. Colo [36] and Hansen et al. [37] demonstrated that individuals who work in universities with high prestige, high reputation, and are high quality are more productive and more often cited. Productivity is also affected by the size of institutions. The size of institutions negatively correlated with productivity [17]. That is, permanent researchers publish more when they are in smaller institutions, which can be explained that smaller institutions will have lower coordination costs, quicker decision-making, lower administrative burden, etc. [18]. Boardman and Corley [38] demonstrated that university centers can be seen as a tool for making interdisciplinary and cross-sector synergies, thus improving research and development. Research centers facilitate their interactions and collaboration by providing their affiliated and external faculty, industry partners, and other stakeholders with resources and interaction opportunities. Thus, for individuals, affiliating researchers can enhance their research capacities by accessing these resources [39]. In addition, in Ponomariov and Boardman's study [40], the probability of researchers who are affiliated with boundary-spanning centers co-authoring with researchers in other fields is higher. In our study, we examined how faculty would behave under the context of this accelerated research University S when surrounded by peers highly engaging in IDR. Therefore, the following hypotheses were proposed concerning the potential peer effects at the school level:

Hypothesis 3a: *There exist positive peer effects between the mean degree of interdisciplinarity at the school level and faculty individual IDR.*

Hypothesis 3b: *There exist positive peer effects between the standard deviation of degree of interdisciplinarity at the school level and faculty individual IDR.*

4.2. Data

As shown in Figure 1, in this study, we constructed a dataset from several sources and follow the procedure below: first, we collected personal profiles for all faculty working at University S. The university faculty profile information is collected through web scrapes for a total of 919 faculty members by the end of December 2020. Second, we use the faculty's unique identifier, including their researcher ID and Scopus researcher ID to obtain their research performance indicators in the last three years (2018–2020) and interdisciplinary information. The bibliometric information of these faculty, such as the number of publications, and the number of citations, came from Elviser's SciVal platform. We obtained data on interdisciplinarity, notably their SciVal subject categories (SCs), which we used to measure the degree to which each faculty's research is interdisciplinary. Third, the two previous datasets were merged to generate a whole dataset with both faculty individual characteristics and research performance. This yielded a cross-sectional dataset that contains both the faculty Curriculum Vitae and bibliometric records [41–44]. We will discuss the definition and present the descriptive statistics of outcome variables in the next section.

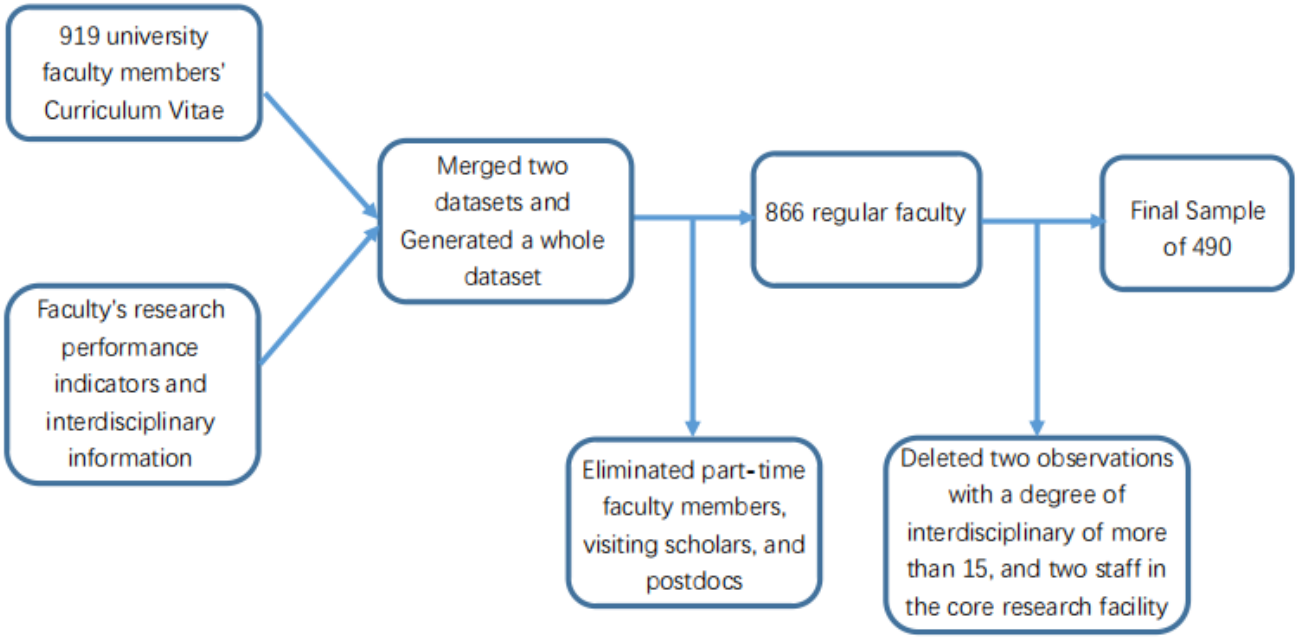

Figure 1. Data Construction Procedure.

There are several rules for sample selection. First, our analysis is limited to the subset of 866 regular faculty. Part-time faculty members, visiting scholars, and postdocs are eliminated from the sample. Next, two observations with a degree of interdisciplinary of more than 15 are deleted because they are likely to be outliers. Similarly, two staff in the core research facility are deleted from the sample. Then, the sample is further reduced to keep only those with a publication record as of 2018–2020 in Scopus because research performance indicators and degree of interdisciplinary research cannot be computed for faculty who have not published during this period. This leaves us with a sample of 499. The final sample for regression analyses is 490.

4.3. Methods

To answer research question 1, we use multivariate regression analyses to assess the effect of interdisciplinary research on faculty research performance outcomes while accounting for relevant control variables. First, the ordinary least squares (OLS) regression analyses were performed to predict research productivity, impact, and prestige. The baseline model includes the indicator for interdisciplinary research and controls for faculty individual characteristics, school fixed effects, and faculty entry year fixed effects is specified as follows:

$$Y_{it} = \alpha + \beta_1 Interdisciplinary_{it} + \gamma X_{it} + \eta_{school} + \mu_{year} + \varepsilon_{it} \quad (1)$$

where Y_{it} is the measures of research performance for faculty i in t time period of 2018–2020; $Interdisciplinary_{\mathrm{it}}$ indicates the faculty i's interdisciplinary research status or degree of interdisciplinarity in 2018–2020; X_{it} includes faculty i's individual characteristic control variables; η_{school} is the school fixed-effects; μ_{year} is the faculty entry year fixed-effects; and ε_{it} is the error term. We cluster standard errors at the school level, accounting for correlation in research performance for faculty in the same school.

Then, the coarsened exact matching (CEM) method is employed to improve the estimation of causal effects of conducting interdisciplinary research given the observational data. CEM is a matching algorithm that eliminates the need for a separate procedure to restrict data to common empirical support and is robust to measurement errors. According to Iacus, King, and Porro [45], CEM provides matching solutions that are better balanced and estimate of the causal quantity of interest that have lower root mean square error than

methods such as based on propensity scores, Mahalanobis distance, nearest neighbors, and optimal matching.

Moreover, since there might exist heterogeneous effects when considering the effect of interdisciplinary research among faculty groups, we assess whether there are heterogeneous effects by including possible interaction terms in model (1).

To test hypothesis 3 about the potential peer effect of interdisciplinary research, we further calculated the mean and standard deviation of the degree of interdisciplinarity at the school level to capture the concentration and variability in faculty interdisciplinarity at the school level.

4.4. Variables

4.4.1. Dependent Variables

Research Productivity. To capture each faculty's quantity dimension of research performance, we relied on the total number of articles published in Scopus journals in the last three years from 2018 to 2020 to measure research productivity. This is a measure of productivity that includes all types of publications such as journal articles, book chapters, and others. It is more accurate than survey data which is usually collected from self-reported publication figures.

Research Impact. We measured an individual's research impact by collecting the Field-Weighted Citation Impact (FWCI) index, citation counts, and the number of citations per publication that had accrued in the Scival Dataset form 2018 through 2020. FWCI in SciVal indicates how the number of citations received by an entity's publications compares with the average number of citations received by all other similar publications in the dataset [46,47]. Citations per publication at the individual level is a more precise personal measure of research impact than publication-level or journal-level measures.

Research Prestige. We measured research prestige by two indicators: outputs in top citation percentiles (OTCP) and publications in top journal percentiles (PTJP) in Scival. OTCP indicates the extent to which a faculty's publications are present in the top 10% of the most-cited publications. It signals the scholar's contribution towards the most influential, highly cited publications in similar disciplines. PTJP indicates the extent to which a faculty's publications are present in the top 10% of the most cited journal indexed by Scopus. The most cited journals are defined by the journal metrics which show the presence of publications in journals that are likely to be perceived as the most prestigious in the world.

4.4.2. Key Independent Variable: Interdisciplinary Research

The key independent variable of interest in this study is measured in two ways. The first way is to generate a dichotomous indicator to show whether the faculty has conducted interdisciplinary research or not. Faculty who have publications in more than one subject category are considered as conducting interdisciplinary research. This variable is a dichotomous indicator (1 = if interdisciplinary, 0 = not interdisciplinary).

The second way is to measure the degree of interdisciplinarity continuously. The continuous variable ranges in value from 1 to 15 with the value 1 indicating single discipline research and the value larger than 1 indicating the faculty has publications in multiple subject categories. It accounts for the diversity of a researcher's publication over scientific domains.

4.4.3. Control Variables

It is necessary to account for other variables that affect the relationship between interdisciplinary research and faculty performance outcomes. Thus, a number of control variables are employed in the multivariate regression models. The first sets of control variables are faculty individual characteristics that may be associated with their research performance. These variables include faculty demographic variables gender, age groups, returnee status, postdoc experience, tenure-track status, and academic ranks. We also

control for four major modes of research collaboration, namely, institutional collaboration, national collaboration, international collaboration, and academic-corporate collaboration to eliminate the effects of other kinds of collaboration.

The variation in interdisciplinary research and academic performance may be due to the difference in fields of study. Therefore, school fixed effect variables are controlled to account for the invariant school characteristics over time. University S has degree programs across six schools including the College of Science (CoS, the reference group), the College of Engineering (CoE), the School of Medicine (SoM), the College of Business (CoB), the School of Innovation and Entrepreneurship (SIE), the School of Humanities and Social Sciences (SHSS), and others.

The sample contains faculty who entered the university across a span of 2011–2021. Therefore, we included entry school year fixed effects variables, which are a series of entry year dummy variables representing the year when the faculty entered this university in the models to account for the fact that some outcomes may be impacted by when they entered the university settings. Faculty who entered University S in 2021 is the omitted reference group.

5. Results

5.1. Descriptive Results

Figure 2 depicts the histogram of the degree of interdisciplinarity for the whole sample. According to Figure 1, only 5.41 percent of the faculty conducting research in a single discipline, with the other 94.59 percent coming from two and more disciplines. Among those who are interdisciplinary, there are divergent differences in the extent or degree of interdisciplinarity held by faculty members. For example, 11.62 percent of the interdisciplinary faculty represented in our sample have publications in two disciplines compared with only 0.2 percent of the faculty who have publications in fifteen disciplines. Most of the faculty have publications concentrating on 2 to 11 subject categories.

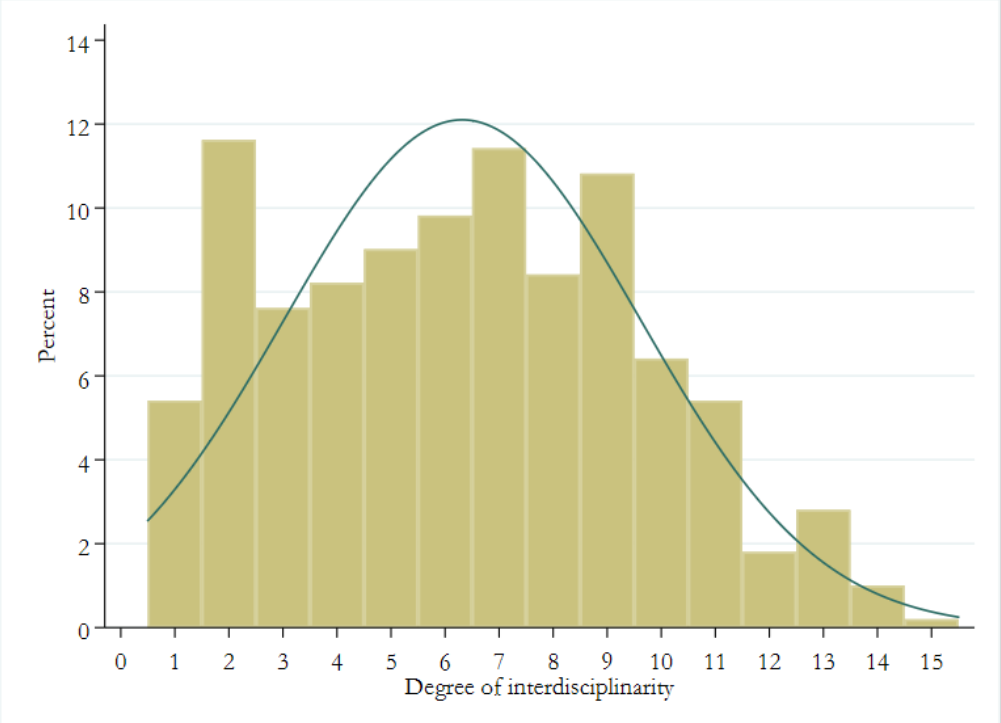

Figure 2. The distribution of the degree of interdisciplinarity.

Figure 3 shows the sample distribution of the average degree of interdisciplinary research by the college in the sampled university. Our data corroborate this: the degree of

interdisciplinarity is higher for faculty in applied science disciplines such as the College of Engineering, School of Innovation and Entrepreneurship, the Academy for Advanced Interdisciplinary Studies, and the School of Medicine, but slightly less for those in schools that concentrate on basic sciences such as science, and humanities and social sciences.

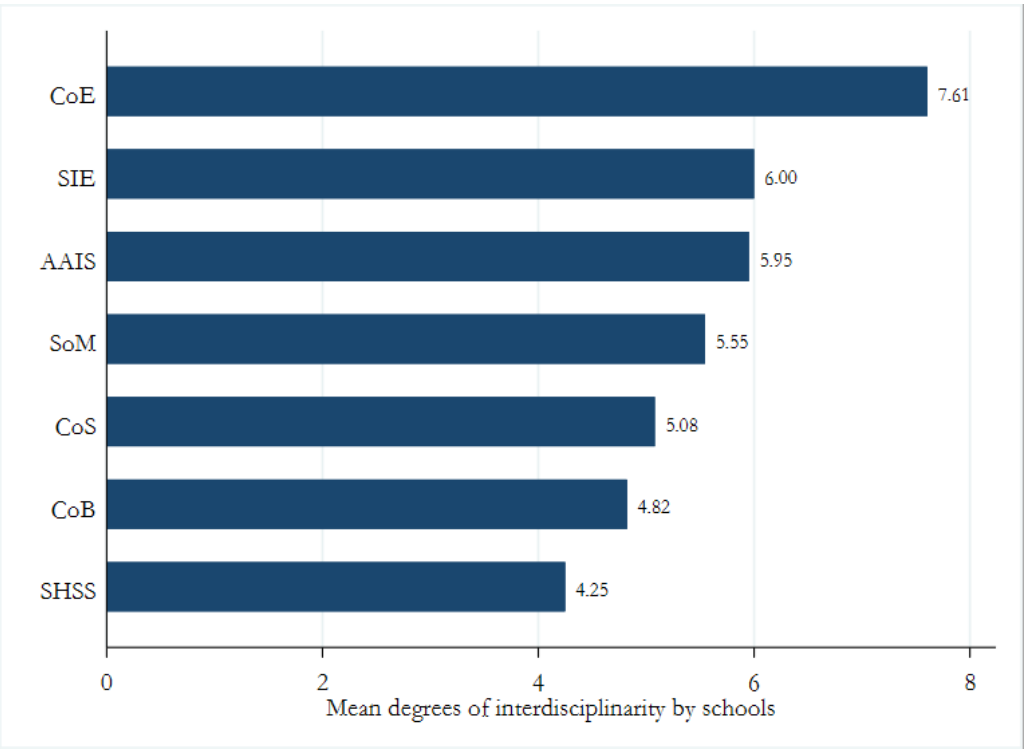

Figure 3. The mean of degree of interdisciplinarity by school. Notes: 1. CoE denotes College of Engineering; SIE denotes School of Innovation and Entrepreneurship; AAIS denotes Academy for Advanced Interdisciplinary Studies; SoM denotes School of Medicine; CoS denotes College of Science; CoB denotes College of Business; and SHSS denotes School of Humanities and Social Sciences. 2. 5.95% of faculty are affiliated with AAIS only; however, some faculty may have dual affiliations in AAIS and in other schools.

Table 1 displays the descriptive statistics for all the dependent and individual level independent variables for the full sample and by interdisciplinary research status. Not all of the key variables of interest (the dependent variables) show statistically significant differences between interdisciplinary and non-interdisciplinary respondents. T-tests reveal that there are significant differences between means for research productivity, impact, and prestige as measured by scholarly output, citation counts, and PTJP. The interdisciplinary faculty members have a higher average number of publications than non-interdisciplinary researchers. The t-test results in Table 1 also indicate that interdisciplinary faculty have significantly higher citation counts and PTJP than their non-interdisciplinary counterparts.

Table 1. Descriptive statistics for full sample and by interdisciplinary research status.

Variables	Full Sample (n = 499)	Non-Interdisciplinary (n = 26)	Interdisciplinary (n = 473)	Mean Differences
Dependent Variables				
Scholarly outputs (2018 to 2020)	20.29	3.23	21.23	−18.00 ***
Field-Weighted Citation Impact (2018 to 2020)	1.86	1.24	1.89	−0.65
Citation counts (2018 to 2020)	265.72	23.12	279.11	−256.00 ***
Citations per publication (2018 to 2020)	12.36	8.05	12.60	-4.55
Outputs in Top Citation Percentiles (OTCP, 2018 to 2020)	0.21	0.18	0.21	−0.03
Publications in Top Journal Percentiles (PTJP, 2018 to 2020)	0.53	0.25	0.55	−0.30 ***
Independent Variables				
Only institutional collaboration (2018 to 2020)	0.15	0.20	0.14	0.06
Only national collaboration (2018 to 2020)	0.30	0.24	0.30	−0.06
International collaboration (2018 to 2020)	0.53	0.45	0.54	−0.09
Academic-corporate collaboration (2018 to 2020)	0.03	0.02	0.04	−0.01
Gender (=1, Male; =0, female)	0.88	0.89	0.88	0.01
Young faculty (=1, yes; =0, otherwise)	0.55	0.63	0.54	0.09
Middle faculty (=1, yes; =0, otherwise)	0.40	0.37	0.40	−0.03
Senior faculty (=1, yes; =0, otherwise)	0.05	0.00	0.06	−0.06
Returnee (=1, yes; =0, otherwise)	0.67	0.78	0.66	0.12
Postdoc experience (=1, yes; =0, otherwise)	0.74	0.67	0.74	−0.08
Tenure-track status (=1, yes; =0, otherwise)	0.80	0.78	0.80	−0.03
Assistant professor (=1, yes; =0, otherwise)	0.27	0.48	0.26	0.22 **
Associate professor (=1, yes; =0, otherwise)	0.39	0.37	0.39	−0.02
Full professor (=1, yes; =0, otherwise)	0.33	0.15	0.34	−0.20 **

Notes: Young faculty are those born in the 1980s and younger; Middle faculty are those born between the 1960s and 1970s; Senior faculty are those born in the 1950s and before. T-tests for differences in means between interdisciplinary and non-interdisciplinary faculty were conducted. Significance: ** $p < 0.05$, *** $p < 0.01$.

The differences in means and proportions are not significant in faculty demographics and research collaborations, but they are obvious for faculty academic rank composition. For example, the distribution of faculty across academic ranks differs for interdisciplinary and non-interdisciplinary faculty. The proportion of non-interdisciplinary faculty is much higher holding assistant professor positions. However, interdisciplinary faculty are more likely to hold full professor ranks.

5.2. The Impact of Interdisciplinary Research on Faculty Performance

Table 2 reports the results obtained from multivariate regression analyses for two panels to examine the interdisciplinary research on faculty research productivity, impact, and prestige, respectively. By both binary measure and continuous measure, the models presented in Table 2 demonstrate that interdisciplinary research has a positive effect on faculty's research performance. Those who conducted interdisciplinary research have significantly more publications than those who did not. Furthermore, faculty engaged in interdisciplinary research have publications with higher research impact and prestige. The results show that in the short-run, interdisciplinary faculty may have advantages over their non-interdisciplinary counterparts in carrying out higher quality and more prestigious research. Meanwhile, we tried to examine how the degree of interdisciplinarity influence research performance and found that the degree of interdisciplinarity promotes faculty's research performance in terms of productivity, impact, and prestige. In other words, when the faculty conducted research in more discipline categories, they tended to perform better.

Table 2. Baseline results.

	# Outputs	FWCI	# Citations	Citations per Publication	OTCP	PTJP
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. binary measure: interdisciplinary vs. non-interdisciplinary						
Interdisciplinary (=1, interdisciplinary)	9.69 ***	0.49	105.62 **	2.74	0.00	0.23 ***
	(2.30)	(0.55)	(32.50)	(3.45)	(0.09)	(0.06)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Entry year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	490	490	490	490	490	490
R-squared	0.33	0.12	0.22	0.15	0.11	0.19
Panel B. continuous measure: the degree of interdisciplinary research						
Interdisciplinary (normalized)	10.27 ***	0.14	169.75 ***	1.92 **	0.04 ***	0.07 **
	(1.30)	(0.15)	(18.99)	(0.71)	(0.01)	(0.02)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Entry year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	490	490	490	490	490	490
R-squared	0.50	0.12	0.36	0.16	0.14	0.20

Notes: Standard errors are clustered at the school level and reported in parentheses. Significance ** $p < 0.05$, *** $p < 0.01$.

Second, we employed the CEM approach to re-estimate the relationship between interdisciplinary research status and faculty's performance to ensure the validity of the estimation, as shown in Table 3. CEM-based causal estimates possess a large variety of other powerful statistical properties, and CEM generated matched data sets with lower imbalance and a larger sample size [47], As a robustness check, the results listed in Table 3 show that the interdisciplinary research status is still significantly associated with research productivity and prestige; however, it is only significantly associated with research impact at the 10% significance level. The CEM approach results are generally consistent with multivariate regression results, which lend further support to our argument from the OLS results. It is also worth noting that the magnitude of coefficients in CEM is larger than that of multivariate regression analyses. It might because that CEM captures the average treatment on the treated (ATT) effect and is based on a reduced sample with more comparable faculty.

Table 3. Robustness check using the coarsened exact matching (CEM) approach.

	Outputs	FWCI	# Citations	Citations per Publication	OTCP	PTJP
	(1)	(2)	(3)	(4)	(5)	(6)
Interdisciplinary (=1, interdisciplinary)	12.75 **	0.91	170.18 *	4.98	0.05	0.25 *
	(4.84)	(0.67)	(74.22)	(4.62)	(0.10)	(0.12)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Entry year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	302	302	302	302	302	302
R-squared	0.37	0.16	0.25	0.20	0.14	0.23

Notes: Standard errors are clustered at the school level and reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$.

Then, considering that the impact of interdisciplinary research status on faculty performance may differ by faculty groups and fields of study, this article further examines the potential heterogeneity by introducing interaction terms between interdisciplinary research status dummy and young faculty group dummy and applied science faculty group dummy in the regression models. As shown in Table 4, the results tell us who reaps more benefits

and who suffers from engagement in interdisciplinary research. The results reveal that the benefits of faculty engagement in interdisciplinary research may not be equally distributed among different faculty age groups. Compared with senior faculty, young faculty may suffer from engagement in interdisciplinary research, especially their research prestige may be negatively affected. This finding is consistent with the previous belief that interdisciplinary research delays career progression, or it is the luxury of senior researchers since it takes a longer time to publish joint interdisciplinary research in high-impact journals. Through another perspective, different research orientations can also yield various results. Faculty in applied-oriented research benefit more from engaging in interdisciplinary research by generating higher quantity and more prestigious publications than faculty in basic sciences.

Table 4. Heterogeneous effect of interdisciplinary research on faculty performance by OLS with interaction terms.

	Outputs	FWCI	# Citations	Citations per Publication	OTCP	PTJP
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. heterogeneity by faculty's working experience						
Interdisciplinary × Young faculty	−7.13 *	0.45	−64.34	6.40 ***	−0.07	−0.20 ***
	(3.06)	(0.30)	(53.37)	(1.67)	(0.08)	(0.03)
Interdisciplinary (=1, yes)	13.96 **	0.22	144.10 *	−1.09	0.04	0.35 ***
	(4.32)	(0.43)	(61.01)	(3.64)	(0.06)	(0.07)
Young faculty (=1, yes)	9.30	0.34	171.66	−2.32	0.15 **	0.31 ***
	(9.76)	(0.44)	(192.62)	(3.07)	(0.05)	(0.07)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Entry year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	490	490	490	490	490	490
R-squared	0.34	0.12	0.22	0.15	0.11	0.19
Panel B. heterogeneity by research orientations						
Interdisciplinary × Applied-oriented research	7.59	1.87	140.68 *	11.61 *	0.32 ***	0.22 **
	(3.97)	(1.00)	(69.42)	(5.71)	(0.04)	(0.07)
Interdisciplinary (=1, yes)	7.44 ***	−0.07	63.60 *	−0.71	−0.10 ***	0.17 ***
	(0.44)	(0.10)	(29.24)	(0.97)	(0.01)	(0.02)
Applied-oriented research (=1, yes)	−13.84 **	−1.90 **	−245.35 **	−15.16 **	−0.44 ***	−0.63 ***
	(4.77)	(0.58)	(98.71)	(5.15)	(0.07)	(0.12)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Entry year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	490	490	490	490	490	490
R-squared	0.34	0.13	0.22	0.15	0.13	0.19

Notes: Young faculty are those born in the 1980s and younger. Faculty in Applied-oriented research means faculty belongs to CoE, SoM, SoB, SIE, AAIS schools, otherwise belongs to basic research. Standard errors are clustered at the school level and reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3. The Peer Effect of Interdisciplinary Research

To test Hypothesis 3, we estimated the relationship between school level mean and standard deviation of the degree of interdisciplinarity and faculty's degree of interdisciplinarity. The results listed in Table 5 suggest that there exist peer effects on faculty's interdisciplinary research behavior, which means the faculty's individual level degree of interdisciplinarity is positively associated with the average degree of interdisciplinarity at the school level, but it is negatively associated with the school level standard deviation of the degree of interdisciplinarity. It echoes the finding that distal disciplinary research might be too risky and more likely to fail, thus disparity of the degree of interdisciplinary research may have a negative effect [30]. The results hold for faculty in both basic and applied-oriented research. The results suggest that the school climate and environment of pursuing and encouraging interdisciplinary research may enhance faculty individual engagement in interdisciplinary research practices and involvement in research with more subject categories. With school peers pursuing publications in a range of subject categories, other faculty will emulate to publish articles across more subject boundaries. However, when the diversity of interdisciplinary subject categories increases, it is less supportive for conducting research in a wide range of subject areas.

Table 5. Regression results of the peer effect of interdisciplinary research.

	(1)	(2)	(3)
	All	**Basic Research**	**Applied-Oriented Research**
Mean of degree of interdisciplinarity	2.21 ***	2.13 ***	1.08 ***
	(0.07)	(0.08)	(0.02)
Standard deviations of degree of interdisciplinarity	−0.84 ***	−0.70 **	−0.57 *
	(0.08)	(0.07)	(0.14)
Controls	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes
Entry year fixed effects	Yes	Yes	Yes
Observations	491	221	270
R-squared	0.29	0.20	0.24

Notes: Faculty in Applied-oriented research means faculty belongs to CoE, SoM, SoB, SIE, AAIS schools, otherwise belongs to basic research. Standard errors are clustered at the school level and reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6. Discussion

First, the results confirmed that interdisciplinary research has significant impacts on faculty research productivity, impact, and prestige. In other words, faculty engaging in interdisciplinary research tend to have more publications and publish more papers with higher impact and in top-tier journals. These results align with the previous studies conducted by Karr [15], which found that research productivity and scientist's interdisciplinarity were positively correlated and it portraits a path to scientific success through a road of collaboration and interdisciplinary exchange, rather than intense focus and specialization. Previous studies examined the academic impact measured by citations revealed that IDR has significant impact on research impact [24,48]. Although previous studies emphasized that IDR are not necessarily of lower quality, they may encounter cognitive and collaborative challenges and more hurdles during peer review and lower productivity [16]. Results from this study suggest IDR promoted by accelerated research universities spurs transformative science and innovation in the short-run and it is beneficial in promoting research performance dimensions including productivity, impact, and prestige. In terms of degree of interdisciplinarity, Yegros-Yegros, Rafols, and Deste [30] stated that the variety of disciplines has a positive effect on impact, whereas balance and disparity have a negative effect. Our findings are consistent with the view that combining multiple fields has a positive effect on knowledge creation. Another study assessed the interdisciplinarity patterns of highly cited papers and found that highly cited papers always exhibit higher variety and disparity [49]. The current study aligns with this literature, confirming the IDR is the most important factor for gaining research prestige.

In addition, similar results were generated from this study that the impacts of conducting interdisciplinary research vary across faculty subgroups. In our study, we found that compared with seniors, young faculty may suffer from conducting interdisciplinary research, while faculty in applied-oriented research or disciplines reap more benefits than those in basic science. Our finding is consistent with the view that high interdisciplinarity is an advantageous strategy for senior scientists, whereas intense focus is optimal for young scientists [15]. This makes sense because existing research usually highlights the tension between innovation gains brought by spanning disciplines and penalty of increasing subject categories, thus the costs and benefits of pursuing IDR depend on characteristics of the field and scientist's place in it [16]. From the career development perspective, a young scientist needs to focus on his or her research fields or interests at the early career stage and shift to broader IDR collaboration as a scientist establishes him/herself. Career goals and planning should also differ for scientists in different scientific career stages and for scientists in various disciplines.

Lastly, we address the peer effects of faculties' IDR behavior, which enriches the literature on faculty research collaboration and interaction in the context of research universities. The average school level degree of interdisciplinarity increases research subject categories at the faculty individual level, while the dispersion of school level interdisciplinarity decreases research subject categories at the faculty individual level. Additionally, the school climate and environment of pursuing and encouraging interdisciplinary research may enhance faculty individual engagement in interdisciplinary research practices and involvement in research with more subject categories. This coincides with Hansen's [37] ideas. Ponomariov and Boardman [40] emphasized the importance of cooperation, while raising the visibility of the early work of scientists who have achieved greater reputation and focusing attention on the work of a lesser known somebody who works with well-known scientists [36]. Our study also recognizes the positive role of collaboration in interdisciplinary.

7. Conclusions

The interdisciplinary research approach was claimed to be desirable for solving global challenges and complex societal problems in which integrating of the insights of different disciplines to provide a more comprehensive solution than can be offered by any given discipline [50], thus interdisciplinary research is essential for sustainability. On the other hand, universities are relevant to sustainable strategies and SDGs [7], through an interdisciplinary research approach to foster innovation and address major scientific challenges [14], which in turn can contribute to a sustainable future.

This study is motivated by these claims to empirically explore the status and degree of interdisciplinary research on faculty's research performance. The conventional school/department system is a major obstacle to interdisciplinarity. Faculty culture can foster a strong professional identity, which may lead to prejudice against other fields. Therefore, how to break the shackles of the original colleges and departments and let scientists from different colleges and departments sit around the same round table and burst out sparks of thinking is an urgent problem to be solved. New Chinese accelerated research universities are taking the lead in this direction. At the same time, many scholars have discussed interdisciplinary research in universities from the organizational level [51–53]. In contrast, our research perspective targets individual faculty members, and, by analyzing their data, we answer the question of whether interdisciplinary research contributes to faculty research performance and thus helps to further develop interdisciplinary research in Chinese universities. Thus, this study contributes to the literature by empirically evaluating the effect of pursuing interdisciplinary research through institutional reforms under the context of building accelerated research universities in China. An understanding of these can provide starting points for the design of policy instruments that stimulate and foster IDR in this transformative development of building world-class universities and innovative higher education systems nationwide.

For university administrators and policymakers who aim to stimulate interdisciplinary research and innovation, the study's findings have significant implications and can provide some ideas for use as a guide.

First, interdisciplinary research has become the main knowledge production mode and faculty conducting interdisciplinary research are prevalent in accelerated research universities. This fact suggests that the recruitment of faculty with an educational background in multiple disciplines or having prior interdisciplinary co-supervision or research working experience might help to increase interdisciplinary activities at the university level. Accelerated research universities manage to maintain a very high proportion of faculty (over 90%) engaging in such research mode. Moreover, since faculty in different schools engage in interdisciplinary research proportionately, it suggests that university administrators should not only embrace policies that pursue multidisciplinary research excessively but also need to consider the traits of discipline and weigh the costs and benefits of involving in IDR.

Second, since the effects of interdisciplinary research are heterogeneous, we advise designing policy instruments to distinguish between young and senior faculty, and faculty in basic and applied sciences or disciplines. Given that young faculty members face the trade-off of publishing interdisciplinary research and obtaining research prestige, universities can offer more help to remove obstacles that hinder a young faculty's willingness to conduct interdisciplinary research. Research institutions that want to vigorously enhance interdisciplinary cooperation should have better evaluation policies designed to coordinate and achieve the balance between research quantity and quality. Faculty in applied-oriented science and disciplines are more likely to conduct interdisciplinary research to gain higher prestige because applied sciences can be a platform where a variety of cutting-edge applied disciplines intersect to obtain high-level innovation results, and many scientists from different disciplines may harness the applied science resources to advance their research.

Third, it seems that interdisciplinary research means choosing a different path with more challenges and risks, and thus requires a supportive environment and efforts. Since one's research subject category decision could be affected by colleagues with a considerable amount of degree of interdisciplinarity, improving the working environment and assigning more co-workers with large research spans in the same school might stimulate a similar pattern of conducting interdisciplinary research. There might be two channels for peer effects in the workplace. One probable channel is that strong peers bring higher pressure, forcing other faculty to conduct interdisciplinary research. Another possibility is that within school spillovers of knowledge and skills through communication and collaboration will promote IDR. Meanwhile, it should be noted that involving in IDR with divergent subject categories might be demanding and it is not necessarily the optimal choice.

Lastly, achieving the SDGs requires interdisciplinary research collaboration and new practices in accelerated research universities in China offer instructive and valuable experiences. The linkages and dynamics of the SDGs are complex, and these dynamics naturally coincide with the technological and application issues that call for multidisciplinary solutions [54]. Addressing the SDGs from an interdisciplinary perspective because an interdisciplinary approach can create a learning setting that stimulates problem solving competencies for sustainability-related issues [55]. Meanwhile, there are still various factors that have resulted in Chinese scholars' low international visibility at present; however, cross-border research collaboration can help relieve these challenges faced by Chinese scholars [56]. As co-innovation arises through collaboration, higher education has been viewed as an "engine" for innovation as well as a "catalyst" for sustainable development [57]; all forms of interdisciplinary research partnerships and co-innovation should be encouraged. Not only the interdisciplinary cooperation at the faculty level but also the building of university-industry co-innovation networks and platforms that offer insights into the norms and cultures of other disciplines. Experiences from accelerated universities elsewhere have already shown that visionary leadership and generous funding combined with innovative ideas such as niche institutions or programs with an interdisciplinary approach can yield impressive results in a short time [58]. The lessons from this sampled university further prove that accelerated research universities in China highlighting IDR achieve significant research performance and academic excellence at the early stage, which becomes an important path for obtaining sustainable and innovation-driven development.

It is important to note several limitations. Although the data used in this study are the best available and retrieved from multiple data sources, it is cross-sectional data and we still need to carefully examine the causality between interdisciplinary research and faculty performance with longitudinal follow-up surveys or administrative data in the future. Despite the ability of this study to directly address the role played by conducting interdisciplinary research in a sampled university, future efforts should attempt to make larger-scale assessments in other higher education institutions currently labeled as accelerated research universities to see how and why this interdisciplinary research movement impacts the research process.

Author Contributions: Overall research design, L.Y.; writing—original draft preparation, L.Y., Y.Y. and M.L.; writing—review and editing, Y.Y. and L.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Education Science Planning Project of Guangdong Province: Research Productivity Evaluation and Promotion for High-level Higher Education Clusters in the Guangdong–Hong Kong–Macao Greater Bay Area (grant number 2019GXJK059), and the National Natural Science Foundation of China: Foreign Asset or Liability? Research on Academic Returnees' Research Productivity in "Double First-Class" Universities (grant number 71904055).

Acknowledgments: We thank Yongye Liu for providing research assistance. Meanwhile, we thank the academic editor and three anonymous reviewers for their contributions to improving the manuscript. Our gratitude is extended to each of the parties listed above.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Villeneuve, D.; Durán-Rodas, D.; Ferri, A.; Kuttler, T.; Magelund, J.; Mögele, M.; Silva, C. What is interdisciplinarity in practice? Critical reflections on doing mobility research in an intended interdisciplinary doctoral research group. *Sustainability* **2019**, *12*, 197. [CrossRef]
2. Ramaswami, A.; Weible, C.; Main, D.; Heikkila, T.; Siddiki, S.; Duvall, A.; Pattison, A.; Bernard, M. A Social-Ecological-Infrastructural systems framework for interdisciplinary study of sustainable city systems an integrative curriculum across seven major disciplines. *J. Ind. Ecol.* **2012**, *16*, 801–813. [CrossRef]
3. Bruno, M.C.; Siviglia, A. Assessing impacts of dam operations—Interdisciplinary approaches for sustainable regulated river management. *River Res. Appl.* **2012**, *28*, 675–677. [CrossRef]
4. Kim, S. Interdisciplinary approaches and methods for sustainable transformation and innovation. *Sutainability* **2015**, *7*, 3977–3983. [CrossRef]
5. Cheng, X.; Pan, W.; Zhang, Q. Antecedents of knowledge interaction in the sustainable interdisciplinary research team: A mixed research method. *Sustainability* **2019**, *11*, 3624. [CrossRef]
6. Griffiths, T.G. Education to transform the world: Limits and possibilities in and against the SDGs and ESD. *Int. Stud. Sociol. Educ.* **2021**, *30*, 73–92. [CrossRef]
7. Alam, G.M.; Roslan, S.; Al-Amin, A.Q.; Leal Filho, W. Does GATS' Influence on Private University Sector's Growth Ensure ESD or Develop City 'Sustainability Crisis'—Policy Framework to Respond COP21. *Sustainability* **2021**, *13*, 4520. [CrossRef]
8. Shechtman, D.; Blech, I.; Gratias, D.; Cahn, J.W. Metallic phase with long-range orientational order and no translational symmetry. *Phys. Rev. Lett.* **1984**, *53*, 1951. [CrossRef]
9. Szell, M.; Ma, Y.; Sinatra, R. A Nobel opportunity for interdisciplinarity. *Nat. Phys.* **2018**, *14*, 1075–1078. [CrossRef]
10. Rhoten, D.; Parker, A. Risks and rewards of an interdisciplinary research path. *Science* **2004**, *306*, 2046. [CrossRef]
11. Qin, J.; Lancaster, F.W.; Allen, B. Types and levels of collaboration in interdisciplinary research in the sciences. *J. Am. Soc. Inf. Sci.* **1997**, *48*, 893–916. [CrossRef]
12. Crane, D. Invisible colleges: Diffusion of knowledge in scientific communities. *Phys. Today* **1972**, *26*, 72. [CrossRef]
13. Clausen, T.; Fagerberg, J.; Gulbrandsen, M. Mobilizing for change: A study of research units in emerging scientific fields. *Res. Policy* **2012**, *41*, 1249–1261. [CrossRef]
14. Leahey, E.; Barringer, S.N.; Ring-Ramirez, M. Universities' structural commitment to interdisciplinary research. *Scientometrics* **2019**, *118*, 891–919. [CrossRef]
15. Karr, J.R.; Hughey, J.J.; Lee, T.K. Scientific Authorship, Collaboration, Interdisciplinarity, and Productivity. *Sci. Geneal.* **2008**, *12*, 1–5.
16. Leahey, E.; Beckman, C.M.; Stanko, T.L. Prominent but less productive: The impact of interdisciplinarity on scientists' research. *Adm. Sci. Q.* **2017**, *62*, 105–139. [CrossRef]
17. Bonaccorsi, A.; Daraio, C. Age effects in scientific productivity. *Scientometrics* **2003**, *58*, 49–90. [CrossRef]
18. Carayol, N.; Matt, M. Individual and collective determinants of academic scientists' productivity. *Inf. Econ. Policy* **2006**, *18*, 55–72. [CrossRef]
19. Rhoten, D.; Pfirman, S. Women in interdisciplinary science: Exploring preferences and consequences. *Res. Policy* **2007**, *36*, 56–75. [CrossRef]
20. Diamond, A.M., Jr. What is a citation worth? *J. Hum. Resour.* **1986**, *21*, 200–215.
21. Katz, J.; Hicks, D. How much is a collaboration worth? A calibrated bibliometric model. *Scientometrics* **1997**, *40*, 541–554. [CrossRef]
22. Evans, J.A. Electronic publication and the narrowing of science and scholarship. *Science* **2008**, *321*, 395–399. [CrossRef] [PubMed]
23. Aldieri, L.; Kotsemir, M.; Vinci, C.P. The impact of research collaboration on academic performance: An empirical analysis for Russian Universities. *MPRA* **2017**, *76408*. [CrossRef]

24. Zhang, L.; Sun, B.; Jiang, L.; Huang, Y. On the relationship between interdisciplinarity and impact: Distinct effects on academic and broader impact. *Res. Eval.* **2021**, *30*, 256–268. [CrossRef]
25. Shi, X.; Adamic, L.A.; Tseng, B.L.; Clarkson, G.S. The impact of boundary spanning scholarly publications and patents. *PLoS ONE* **2009**, *4*, e6547. [CrossRef] [PubMed]
26. Aldieri, L.; Kotsemir, M.; Vinci, C.P. The impact of research collaboration on academic performance: An empirical analysis for some European countries. *Socio-Econ. Plan. Sci.* **2018**, *62*, 13–30. [CrossRef]
27. Lowe, P.; Phillipson, J. Reflexive interdisciplinary research: The making of a research programme on the rural economy and land use. *J. Agric. Econ.* **2006**, *57*, 165–184. [CrossRef]
28. Stirling, A. On the economics and analysis of diversity. Sci. Policy Res. Unit (SPRU) Electron. *Work. Pap. Ser. Pap.* **1998**, *28*, 1–156.
29. Cummings, J.N.; Kiesler, S. Collaborative research across disciplinary and organizational boundaries. *Soc. Stud. Sci.* **2005**, *35*, 703–722. [CrossRef]
30. Yegros-Yegros, A.; Rafols, I.; D'este, P. Does interdisciplinary research lead to higher citation impact? The different effect of proximal and distal interdisciplinarity. *PLoS ONE* **2015**, *10*, e0135095. [CrossRef] [PubMed]
31. Larivière, V.; Gingras, Y. On the relationship between interdisciplinarity and scientific impact. *J. Am. Soc. Inf. Sci. Technol.* **2010**, *61*, 126–131. [CrossRef]
32. Wang, J.; Thijs, B.; Glänzel, W. Interdisciplinarity and impact: Distinct effects of variety, balance, and disparity. *PLoS ONE* **2015**, *10*, e0127298. [CrossRef]
33. Bird, E. Disciplining the interdisciplinary: Radicalism and the academic curriculum. *Br. J. Sociol. Educ.* **2001**, *22*, 463–478. [CrossRef]
34. Evans, H.M.; Macnaughton, J. Should medical humanities be a multidisciplinary or an interdisciplinary study? *Med. Humanit.* **2004**, *30*, 1–4. [CrossRef] [PubMed]
35. Klein, J.T. *Crossing Boundaries: Knowledge, Disciplinarities, and Interdisciplinarities*; University of Virginia Press: Charlottesville, VA, USA, 1996; pp. 154–196.
36. Cole, S. Professional standing and the reception of scientific discoveries. *Am. J. Sociol.* **1970**, *76*, 286–306. [CrossRef]
37. Hansen, W.L.; Weisbrod, B.A.; Strauss, R.P. Modeling the earnings and research productivity of academic economists. *J. Political Econ.* **1978**, *86*, 729–741.
38. Boardman, P.C.; Corley, E.A. University research centers and the composition of research collaborations. *Res. Policy* **2008**, *37*, 900–913. [CrossRef]
39. Bozeman, B.; Dietz, J.S.; Gaughan, M. Scientific and technical human capital: An alternative model for research evaluation. *Int. J. Technol. Manag.* **2001**, *22*, 716–740. [CrossRef]
40. Ponomariov, B.L.; Boardman, P.C. Influencing scientists' collaboration and productivity patterns through new institutions: University research centers and scientific and technical human capital. *Res. Policy* **2010**, *39*, 613–624. [CrossRef]
41. Sandström, U. Combining curriculum vitae and bibliometric analysis: Mobility, gender and research performance. *Res. Eval.* **2009**, *18*, 135–142. [CrossRef]
42. Moed, H.F.; Halevi, G. A bibliometric approach to tracking international scientific migration. *Scientometrics* **2014**, *101*, 1987–2001. [CrossRef]
43. Aman, V. A new bibliometric approach to measure knowledge transfer of internationally mobile scientists. *Scientometrics* **2018**, *117*, 227–247. [CrossRef]
44. Robinson-Garcia, N.; Sugimoto, C.R.; Murray, D.; Yegros-Yegros, A.; Larivière, V.; Costas, R. The many faces of mobility: Using bibliometric data to measure the movement of scientists. *J. Informetr.* **2019**, *13*, 50–63. [CrossRef]
45. Iacus, S.M.; King, G.; Porro, G. Multivariate matching methods that are monotonic imbalance bounding. *J. Am. Stat. Assoc.* **2011**, *106*, 345–361. [CrossRef]
46. SciVal Quick Reference Guide. Available online: https://p.widencdn.net/yvftvp/ACAD_RL_SV_QRG_SciVal_Quick_Reference_Guide_WEB (accessed on 27 July 2022).
47. Research Metrics Guidebook. Available online: https://elsevier.widen.net/s/chpzk57rqk/acad_rl_elsevierresearchmetricsbook_web (accessed on 27 July 2022).
48. Larivière, V.; Haustein, S.; Börner, K. Long-distance interdisciplinarity leads to higher scientific impact. *PLoS ONE* **2015**, *10*, e0122565. [CrossRef]
49. Chen, S.; Qiu, J.; Arsenault, C.; Larivière, V. Exploring the interdisciplinarity patterns of highly cited papers. *J. Informetr.* **2021**, *15*, 101124. [CrossRef]
50. Ng, D.; Litzenberg, K. Overcoming disciplinary divides in higher education: The case of agricultural economics. *Palgrave Commun.* **2019**, *5*, 26. [CrossRef]
51. Bolger, P. Delivering on the promise: How are sustainability research institutes enabling interdisciplinary research? *Int. J. Sustain. High. Educ.* **2021**, *22*, 167–189. [CrossRef]
52. Bednarek, R.; e Cunha, M.P.; Schad, J.; Smith, W. The value of interdisciplinary research to advance paradox in organization theory. In *Interdisciplinary Dialogues on Organizational Paradox: Learning from Belief and Science*; Emerald Publishing Limited, Emerald Insight: Bingley, UK, 2021; Volume 3.
53. Townsend, T.; Pisapia, J.; Razzaq, J. Fostering interdisciplinary research in universities: A case study of leadership, alignment and support. *Stud. High. Educ.* **2015**, *40*, 658–675. [CrossRef]

54. Mwitondi, K.S.; Munyakazi, I.; Gatsheni, B.N. A robust machine learning approach to SDG data segmentation. *J. Big Data* **2020**, *7*, 97. [CrossRef]
55. Alm, K.; Melén, M.; Aggestam-Pontoppidan, C. Advancing SDG competencies in higher education: Exploring an interdisciplinary pedagogical approach. *Int. J. Sustain. High. Educ.* **2021**, *22*, 1450–1466. [CrossRef]
56. Liu, Y.; Ma, J.; Song, H.; Qian, Z.; Lin, X. Chinese universities' cross-border research collaboration in the social sciences and its impact. *Sustainability* **2021**, *13*, 10378. [CrossRef]
57. Cai, Y.; Ma, J.; Chen, Q. Higher education in innovation ecosystems. *Sustainability* **2020**, *12*, 4376. [CrossRef]
58. Altbach, P.G.; Reisberg, L.; Salmi, J.; Froumin, I. (Eds.) *Accelerated Universities: Ideas and Money Combine to Build Academic Excellence*; Brill Sense: Leiden, The Netherlands, 2018; pp. 1–13.