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Impact of Transnational Research Collaboration on Universities' Innovation Performance: Panel Data Research of 64 Chinese Universities from 2009 to 2019

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Abstract: Recently, China launched policies to further internationalize Chinese universities, including the "First-Class Universities and First-Class Disciplines Project" (Double First-Class Project), which highlights the importance of increasing transnational research collaboration activities. However, little is known about the actual impacts of these national initiatives on universities' transnational research collaboration activities. Research on the impact of the involvement of transnational research collaboration on universities' innovation performance is lacking. The purpose of this study was (1) to further understand the link between the involvement of transnational research collaboration and the innovation performance of universities and (2) to examine the relation between the "Double First-Class Project" and transnational research collaboration in Chinese universities. Through collecting and analyzing 576 panel data (a combination of cross-sectional series data and time series data) on the involvement of transnational research collaboration and the innovation performance of 64 universities from 2009 to 2019, the study manifested a positive correlation between the involvement of transnational research collaboration and the innovation performance of universities. The study further indicated the national key university initiative had a direct positive impact. More meso-level studies and a more open international mindset from policymakers to maintain the sustainable development of research and innovation globally are needed.

Keywords: transnational research collaboration; international academic mobility; innovation performance; "Double First-Class" Project; China

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1. Introduction

Energy shortages and environmental pollution make the traditional economic development model unsustainable. Innovation has gradually become a powerful engine of national and regional economic sustainable development. With the rapid development of a knowledge economy, universities have become an important source of knowledge flow innovation systems [1]. Universities provide critical infrastructure for scientific research and technological innovation [2], which positions them at the forefront of scientific research and innovation. Furthermore, universities, which are actors in the connotative development of higher education, enable significant and competitive enhancement of a country's national science and technology [3].

International scientific research cooperation by universities has played an important role [4]. The knowledge flow of scientific research innovation across national borders vigorously promotes scientific research and industrial transformation worldwide. Through integrating the global advanced science and technology resources, international scientific research cooperation, usually in combination with international mobility, can effectively solve the frontiers of scientific research problems and address complex challenges in interdisciplinary research [5]. Moreover, it can further provide different cooperation paths and modes, owing to the diversity of cooperation partners' positive impacts on innovation performance [6]. Recognizing the importance of international research cooperation for university research and innovation performance, past research on higher education and scientific research management has explored the influencing factors and enabling mechanisms of university innovation performance and points to the impacts of government policy support.

In the Chinese context, past studies have drawn our attention to the impacts of policies of world-class universities. For instance, Dong and Liu (2017) analyzed the evolution of institutional cooperation networks in Chinese universities and found that first-class universities in developed countries have long been at the forefront of the institutional cooperation network, and top institutions are likelier to form large-scale agglomerative subgroups [7]. Hong and Gao (2020) compared the performance and characteristics of first-class universities in China and the U.S. regarding the co-authorship network [8].

To avoid repetition, we further illustrate the previous findings from the literature in our next section. Although various studies have explored the characteristics of scientific research cooperation networks and the influencing factors of scientific research innovation performance, few studies have explored the influence of international scientific research cooperation on innovation performance in China. Therefore, it is of theoretical and practical significance to identify the key factors influencing the scientific research performance of universities through international scientific research cooperation, particularly in the context of the implementation of the "Double First-Classes Project" in China.

We took 576 pieces of panel data from universities directly under the jurisdiction of the Ministry of Education in China from 2009 to 2019 to analyze the correlation between international scientific research cooperation intensity and the overall innovation performance of universities at the organizational level. This paper uses the dynamic panel data model of system generalized moment (Sys-GMM) to conduct an empirical study of the innovation performance growth of comprehensive universities and professional universities.

This paper aims to study the impact of China's university transnational research cooperation on the overall innovation performance and the moderating effect of university types in the impact mechanism. The subsequent parts of the paper are organized as follows. Section 2 reviews the literature on the impact of transnational research collaboration on universities' innovation performance and puts forward the research hypothesis. Research methods and variable refinement are discussed in Section 3, followed by Section 4, which presents the findings and their analysis. The conclusion is proposed in Section 5. The main contribution of this paper is that it reveals the correlation between transnational research collaboration and universities' research performance in China's context.

2. Theoretical Background and Hypotheses

Since the 1990s, the rapid development of the internet has promoted the globalization of information and ideas. Universities around the world have been involved in an expanding global knowledge production network. According to the literature, existing research focuses more on the impact of the strength of an international scientific research cooperation activity on a certain innovation index. For example, Barjak (2008) pointed out that international collaboration has a positive impact on the quality and quantity of the scientific research outputs of EU research teams [9]. Goldfinch et al. (2003), through the investigation and analysis of nine national research institutions in New Zealand, concluded that a large number of countries, authors, and institutions involved in international cooperation has a positive impact on the citation of a paper [10]. Frederiksen (2004), who analyzed the impact of international scientific research cooperation among different disciplines and the number of paper collaborators on the research citation of Danish industrial institutions, found that the papers produced by international scientific research cooperation have a significant impact on the citation rate of papers [11].

Research on Chinese universities found similar conclusions. Xiaolin (2019), from an overall analysis of the citation influence of various discipline papers during the 12th Five Year Plan period, discovered that the citation influence of international cooperation papers is significantly higher than that of discipline papers, which means the influence of international cooperation on disciplines is significantly beneficial [12]. Miao Yajun et al. (2014) took the highly cited papers of 985 universities in China included in the Web of Science database as their sample [13]. After a scientific econometric analysis, they concluded that the international scientific research cooperation of universities has a significant positive correlation with the number and influence of papers.

However, at present, communication between different disciplines is becoming stronger. Some studies have found that when a university as a whole is analyzed at the organizational level, the results are controversial. Admas et al. (2005) conducted research based on literature data published by the top 110 universities in the United States. Their results showed that the international collaboration of research institutions has a positive impact on the frequency of paper citations, but there is a negative correlation with scientific productivity [14]. In related research of the industry, it has also been found that too much scientific research collaboration hinders an organization's absorptive capacity and independent innovation ability and damages the accumulation and creation of internal knowledge [15]. The interaction of these different effects of research collaboration on the innovation performance of an institution makes it have a non-linear impact on the improvement of innovation performance. There is an inverted U-shaped relationship between enterprise scientific research collaboration and performance [16]. International cooperation and exchange are no longer carried out in a single discipline or by a single team, but via big projects amid globalization.

The study of international scientific research collaboration activities in this article not only focuses on micro-team collaboration but also increases the perspective of organizational measurement through statistics and analysis of an organization's overall R&D investment and innovation performance data. Based on the current research conclusions of universities and enterprises, hypothesis H1 is as follows:

H1. *The intensity of international research cooperation of a university has an inverted U-shaped impact on its innovation performance.*

The characteristics of colleges and universities will have a certain impact on the scientific research activities of colleges and universities. Pan et al. (2009), studying the classification of international education standards after analyzing the actual situation of China's higher education, showed that different types of universities carry out international scientific research cooperation with different objects, modes, intensities, and frequencies, and the corresponding innovation performance also differs [17].

Evans et al. (2011) showed that the research field, the identity of the scholars, and the location of institutions all have an impact on cooperation in the field of economy and management [18]. In addition, Huang (2018) pointed out that the higher the number of high-level personnel in a university, the stronger the innovation ability and the higher the efficiency of scientific research [19].

Since 2017, the Chinese government has established global first-class universities and provided 42 universities in China with special financial support for each period of five years. These universities, which have received special financial funds, represent the highest level of Chinese universities and drive in-depth scientific research collaboration and equal dialogue with other high-level international scientific research institutions. They can also gain complementary advantages through international scientific research collaboration and resource sharing. For example, Wang et al. (2019) analyzed 41,104 articles in 137 natural science journals and 16,383 articles in 104 social science journals in the Chinese national knowledge infrastructure database and found that the number of high-quality research results issued by "Double First-Class Universities" in the fields of natural science and social science is much higher compared to other types of universities [20].

In this paper, the types of universities are added as a regulatory variable when constructing a model of the impact mechanism of international scientific research cooperation and innovation performance of colleges and universities. The sample colleges and universities participating in the research are divided into two categories: those that have obtained the construction support of the "Double First-Class Project" and those that have not.

This paper studies the moderating effects of different types of colleges and universities on the overall scientific research performance of colleges and universities. These assumptions are part of hypothesis H2.

H2. *University type has a significant moderating effect on the relationship between international research collaboration personnel exchange and the innovation performance of a university.*

The conceptual framework of the study and hypotheses are depicted below in Figure 1.

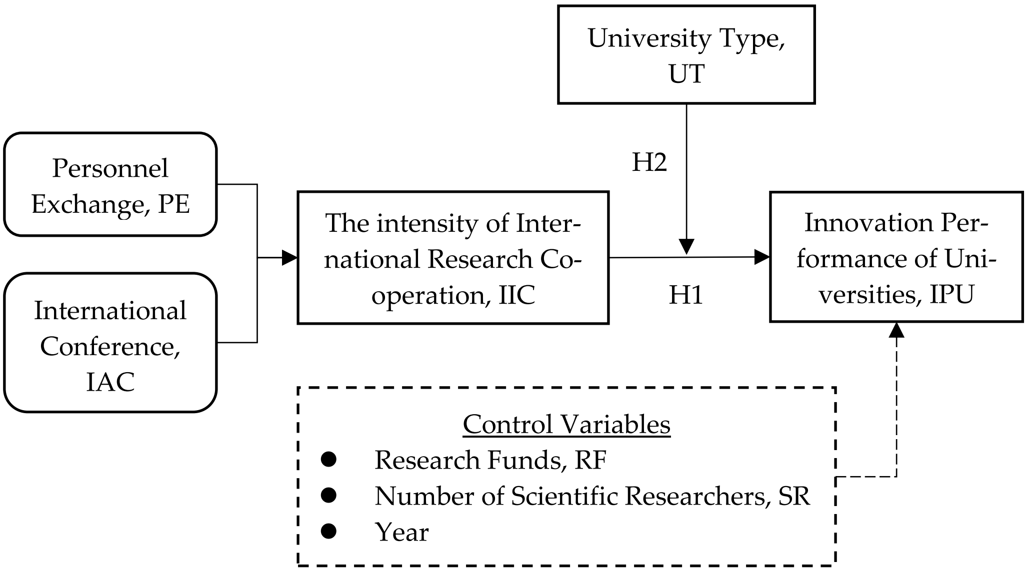

Figure 1. Conceptual Framework.

3. Data and Methodology

3.1. Empirical Data and Sample Selection

This study aims to determine the factors affecting the innovation performance of universities in China. There are currently 64 universities under the direct management of the Ministry of Education in China. As representatives of Chinese universities, they have played an exemplary role in teaching, scientific research, and social services. In this study, we used secondary data based on a deductive methodology from 2009 to 2019 from 64 Chinese universities administrated by the Ministry of Education of China in STATA 15. The sample data were collected from the "Compilation of Science and Technology Statistics of Higher Education Institutions" published by the Ministry of Education of China from 2010 to 2020, which provides detailed information on the scientific research human resource, funding, institutions, projects, international communication, achievements, and technology transfer of universities in China from 2009 to 2019. According to the research needs and the availability of data, 704 panel data from 64 colleges and universities directly under the Ministry of Education in China in the past 11 years were selected as observation samples.

The dependent variable is the innovation performance of a university (IPU). Guler (2010) used the number of patents and papers as indicators to measure the country's innovation performance [21], and Bozeman and Lee (2005) used the total number of academic papers published annually to measure the innovation performance of universities [22]. The indicators that the Ministry of Education of China considers for the statistics of scientific and technological achievements of its universities each year include the publication of scientific and technological works, academic papers, national-level research projects, patent status, and other intellectual property rights [23].

In this paper, we selected the number of scientific and technological works, published academic papers, and national-level research projects per year of a university, and integrated them into a comprehensive indicator by principal component analysis (PCA) to observe the innovation performance of the university.

The process of international scientific research collaboration is a process of sharing resources, which includes personnel dispatch and exchanges, international academic conferences, collaborative construction of research platforms, technology introduction, and collaborative publications. In essence, collaborative publications and the collaborative construction of research centers are often the results of the work of university researchers under certain circumstances (such as academic visits and international conferences). In some studies, indicators such as the number of international collaborative papers are considered the result of collaboration to measure collaboration performance [24].

In this paper, we consider the intensity of international research collaboration of universities (IIC) from two dimensions: personnel exchanges (PE) and international academic conferences (IAC). According to the statistics of the Ministry of Education of China, the annual number of personnel dispatched abroad, personnel receiving visits from abroad, and personnel participating in international academic conferences are selected to reflect the independent variables of PE. Meanwhile, the number of international conferences sponsored by universities each year was selected as the variable of IAC. Therefore, based on hypothesis H1, we propose hypothesis H1a, which is that international personnel exchange has an inverted U-shaped impact on the innovation performance of universities, and H1b, which is that university international academic conferences have an inverted U-shaped impact on the innovation performance of universities.

The moderating variable is the type of university (UT), which is divided into two categories according to whether it is supported by special financial funds for the construction of global first-class universities. The construction plan started in 2017, and the panel data analyzed in this study is from 2009. In fact, the Chinese government's special construction plans for these universities have been in existence since the 1990s. Among them, the "985 Project" started in 1998, and the current construction plan "Double First-Class Project" is considered a continuation of the "985 Project": both of which are national strategies proposed by the central government to enhance comprehensive strength; the universities supported by these two plans are almost the same and the 39 universities listed in the "985 Project" have also been supported by the construction of the "Double First-Class Project".

To discuss the impact of international cooperation on the innovation performance of universities under different university types, we divided the 64 universities directly under the Ministry of Education into two categories according to whether they are currently supported by the "Double First-Class Project" construction plan. Therefore, based on hypothesis H2, we propose the alternative hypothesis H2a, which is that university type has a significant moderating effect between international personnel exchange and the innovation performance of universities, and H2b, which is that university type has a significant moderating effect between international academic conferences and the innovation performance of universities. The classification of 64 universities directly under the Ministry of Education of China is shown in Table 1.

Controlling factors such as research funding (RF), number of scientific researchers (SR), and time also have an impact on the innovation performance of universities. Therefore, the above three variables are included in the model as control variables. Research funding for a Chinese university mainly includes government funds, enterprises and institutions entrusted funds, and other funds. "Government funds" refers to the scientific research funds allocated by the government to all kinds of universities at all levels. The entrusted funds of enterprises and institutions are obtained by universities from foreign enterprises and institutions, which include the funds allocated by the research institutes of the Chinese Academy of Sciences. Other funds are obtained through other channels for research, development, and scientific and technological services in the current year.

Table 1. List of two types of universities directly administrated by the Ministry of Education of China.

University Type	Number of Samples	List of Universities
The selected first-class universities in the "Double First-Class Project" (referred to as "First-class Universities" in short afterward)	33	Peking University, Renmin University of China, Tsinghua University, China Agricultural University, Beijing Normal University, Nankai University, Tianjin University, Dalian University of Technology, Northeast University, Jilin University, Northeast Forestry University, Fudan University, Tongji University, Shanghai Jiaotong University, East China Normal University, Nanjing University, Southeast University, Zhejiang University, Xiamen University, Shandong University Ocean University of China, Wuhan University, Huazhong University of Science and Technology, Hunan University, Central South University, Sun Yat-sen University, South China University of Technology, Chongqing University, Sichuan University, University of Electronic Science and Technology, Xi'an Jiaotong University, Northwest University of Agriculture and Forestry Science and Technology, Lanzhou University
Other universities	31	Beijing Jiaotong University, Beijing University of Science and Technology, Beijing University of Chemical Technology, Beijing University of Posts and Telecommunications, Beijing Forestry University, Beijing University of Traditional Chinese Medicine, Communication University of China, China University of Political Science and Law, North China Electric Power University, China University of Mining and Technology (Beijing), China University of Petroleum (Beijing), China University of Geosciences (Beijing), Northeast Normal University, East China University of Technology, Donghua University, China University of Mining and Technology, Hehai University, Jiangnan University, Nanjing Agricultural University, China Pharmaceutical University, Hefei University of Technology, China University of Petroleum (East China), China University of Geosciences (Wuhan), Wuhan University of Technology, Central China Agricultural University, Central China Normal University, Southwest University, Southwest Jiaotong University, Xi'an University of Electronic Science and Technology, Chang'an University and Shaanxi Normal University

Because the amount of research funding has a certain impact on the output of innovation performance, it is included as a control variable in the model. However, due to the large number of scientific research funds, we used Zhang's (2018) method to process the funds' data and changed the unit of scientific research funds from yuan to 10,000 yuan in order to avoid the large difference between the control variable and other variables, which was likely to result in the change of the stability of the data [25].

The indicator of the number of scientific researchers was selected from the statistics of the Ministry of Education for the number of full-time personnel in R&D. Meanwhile, during the 2009 to 2019 period under study, China's economic, social, and technological development underwent tremendous changes, and academic research and innovation output has also been affected by changes over time.

It is necessary to control the impact of time on the model. We use years as the unit of time and calculate it in the form of dummy variables. The definition and basis of each variable are shown in Table 2.

Table 2. Operational definitions of variables and measurements.

Variable Type	Variable	Variable Content
Dependent Variable	Innovation Performance of Universities, IPU	The number of scientific and technological works, the number of published academic papers, and the number of national research projects each year of the university
Independent Variable	The intensity of International Research Cooperation, IIC	Personnel Exchange, PE: Number of dispatched personnel, number of accepted personnel, and number of personnel attending international conferences. International Conference, IAC: the number of international academic conferences held by the university every year
Moderator	University Type, UT	Whether to obtain special financial support
Control Variable	Research Funds, RF	The sum of government funds, enterprises and institutions entrusted funds, and other funds received by the university every year.
	Number of Scientific Researchers, SR	The full-time equivalent of R&D personnel
	Year	Year dummies during 2009–2019

3.2. Model Specification

Panel data are a combination of cross-sectional series data and time series data. Building a dynamic panel model based on panel data can solve the endogenous problems caused by missing variables, measurement errors, or the model's own causes. It can effectively avoid biased and non-uniform problems caused by random effects or OLS fixed-effect methods [23].

The panel data used in this paper came from 64 universities in China from 2009 to 2019. Since the level of innovation capacity is a dynamic evolution process, it is suitable to use a dynamic panel estimation model for quantitative dynamic analysis. The GMM model is often used in the dynamic panel estimation model. The GMM model includes the differential generalized method of moments (DIF-GMM) model and the system generalized method of moments (Sys-GMM) model. DIF-GMM removes the effects of individual effects by making first-order differences in the equations. It eliminates the problem of incomplete estimation caused by variables that do not change over time [26]. Sys-GMM has high estimation efficiency and retains variable coefficients that do not change over time. In addition, it can flexibly select instrumental variables so that the estimation results have less bias [27]. A basis criterion for Sys-GMM application is N (the number of cross-sections) > T (period), which was fulfilled by the data of this study, where T = 11 and N = 64 (N > T).

To ensure the reliability and accuracy of the regression results, we need to test the quality of the selected data for multicollinearity and stationarity when using panel data for econometric demonstration. Specifically, we mainly tested the stability of panel data and the collinearity before variables. The multicollinearity test is used to test whether the autocorrelation problem exists in the disturbance term, and the stationarity test is used to test whether the data samples tend to be stationary [28].

Second, the over-identification constraint test and the autocorrelation of residual sequence are carried out, including the over-identification constraint test to test the effectiveness of the instrumental variables selected in the model and the residual sequence autocorrelation test to test the overall robustness of the model.

The empirical analysis part of this paper first tests the overall data and then carries out descriptive statistics and regression analysis. It verifies whether the international research collaboration activities of universities directly under the Ministry of Education of China have a direct impact on the innovation performance of universities and whether the types of universities have a moderating effect.

The general form of the dynamic panel model is as follows:

$$y_{it} = \alpha y_{it-1} + \beta X_{it} + u_i + \varepsilon_{it}$$

where i denotes the cross-sectional units, of which there are 64 in our sample, and t expresses time, which is 11 years in our sample; y_{it-1} is the first-order lag variable of the explained variable, reflecting the influence of historical behavior on current behavior. X_{it} is the explanatory variable, u_i is the misspecific variable, and ε_{it} is the random error term.

In order to test the non-linear hypotheses H1a and H1b, we constructed non-linear dynamic panel models of the intensity of university international research cooperation innovation performance of universities from two aspects: personnel exchange and international academic conferences. The non-linear dynamic models of this study can be written as follows:

$$IPU_{it} = \alpha_0 + IPU_{i,t-1} + \alpha_2 PE_{it} + \alpha_3 {PE_{it}}^2 + \alpha_4 RF_{it} + \alpha_5 SR_{it} + \alpha_6 year + \varepsilon_{it} \quad (1)$$

$$IPU_{it} = \alpha_0 + IPU_{i,t-1} + \alpha_2 IAC_{it} + \alpha_3 {IAC_{it}}^2 + \alpha_4 RF_{it} + \alpha_5 SR_{it} + \alpha_6 year + \varepsilon_{it} \quad (2)$$

where *IPU* represents the innovation performance of universities, *PE* represents the personnel exchange, *IAC* represents the international academic conferences, *RF*, *SR,* and *year* are the control variables representing research funding, scientific researcher, and time respectively. If α_2 is positive and α_3 is negative, it indicates that *PE* and *IAC* have an inverted U-shaped relationship with *IPU,* respectively, and hypotheses H1a and H1b can be verified.

Moreover, in order to discuss the moderating effect of the type of university on the relationship between the international research collaboration intensity and the innovation performance of the university, and to test hypotheses H2a and H2b, the interactions between moderator and independent variables are introduced into the models. The moderating impact of university-type interaction terms can be written as follows:

$$IPU_{it} = \alpha_0 + IPU_{i,t-1} + \alpha_2 PE_{it} + \alpha_3 PE_{it2} + \alpha_4 PE_{it} \times UT + \alpha_5 PE_{it2} \times UT + \alpha_6 UT + \alpha_7 RF_{it} + \alpha_8 SR_{it} + \alpha_9 year + \varepsilon_{it} \quad (3)$$

$$IPU_{it} = \alpha_0 + IPU_{i,t-1} + \alpha_2 IAC_{it} + \alpha_3 IAC_{it2} + \alpha_4 IAC_{it} \times UT + \alpha_5 EIAC_{it2} \times UT + \alpha_6 UT + \alpha_7 RF_{it} + \alpha_8 SR_{it} + \alpha_9 year + \varepsilon_{it} \quad (4)$$

where *UT* represents the types of universities, *PE*UT* and PE^2**UT* are the interaction terms between personnel exchange and the university types, whereas *IAC*UT* and IAC^2**UT* refer to the interaction terms between international academic conferences and university types. If the coefficients of interaction terms α_4 and α_5 are significant, it indicates that the moderating effect of university types is significant, and hypotheses H2a and H2b can be verified.

4. Data Analysis and Results

4.1. Preliminary Analysis

Table 3 shows the descriptive statistics of the selected dependent and independent variables and presents the summary statistics in terms of the mean, standard deviation, minimum and maximum values, skewness, Kurtosis, and observation count. All variables are based on 704 observations from 64 universities over 11 years from 2009 to 2019.

Table 3. Descriptive statistics.

Variables	Obs	Mean	Std. Dev.	Min	Max	Skew	Kurt
IPU	704	4383	3711.0	27	31,156	1.90	8.83
PE	704	471.5	621.5	0	4530	2.99	14.40
IAC	704	15.81	20.18	0	160	2.98	14.63
RF	704	918.7	913.1	0.124	6588	2.23	9.59
SR	704	858.4	770.2	9	5659	2.50	11.80
UT	704	1.5	0.2	1	2	0.06	1.00

Table 3 shows the pairwise correlation between the variables. The results of first-class universities show that PE and IAC have a robust positive correlation with the innovation performance of universities at a 1% significance level. Innovation performance of universities increases as the concentration of PE and IAC increases. However, control variables RF and SR have a highly significant and positive relationship with the innovation performance of universities at a 1% significance level. The moderating variable ST also positively correlates with the innovation performance of universities at a 1% significance level. All independent variables showed a 1% significance level. In this study, a significant correlation exists between the innovation performance of universities, and the explanatory findings have strongly supported our research objective and hypotheses.

In order to ensure the reliability of the Sys-GMM estimation results and avoid the problem of "spurious regression," it is necessary to test the stationarity of the panel residuals of the Sys-GMM estimation results. If it is stationary, the results are reliable; otherwise, they are not reliable. Table 4 demonstrates the stationary data through LLC and IPS unit root methods. Stationary test results show that all variables are stationary at a significance at the 1% level, rejecting the null hypothesis of "panel residuals are not stationary", thus indicating that the results of the dynamic panel data model estimated by Sys-GMM in this paper are valid.

Table 4. Pairwise correlations.

	IPU	**PE**	**IAC**	**RF**	**SR**
IPU	1				
PE	0.505 ***	1			
IAC	0.585 ***	0.553 ***	1		
RF	0.659 ***	0.532 ***	0.661 ***	1	
SR	0.614 ***	0.431 ***	0.568 ***	0.632 ***	1

Note: *** $p < 0.01$ indicate significance at the 1% level.

This paper also pays attention to possible multicollinearity and uses Stata15SE for panel data testing. Strictly collinear variables will be automatically eliminated by Stata. The calculated value of variance inflation factors (VIF) between the explanatory variables of the models are all less than 10, and the mean VIF of the models is 1.86. Moreover, from the test results shown in Tables 5 and 6, the *t*-tests of the core variables were found to be significant and in line with economic expectations. Chen (2016) [29] believes that if multicollinearity affects the significance of the core variables, it should be dealt with. However, if multicollinearity does not affect the significance of the core variables, it is not necessary to deal with it, because if there is no multicollinearity, the coefficient of the variable will only be more significant.

Table 5. Results of unit root tests.

Variables	**LLC Test**	**IPS Test**
IPU	−55.6977 ***	−9.5298 ***
PE	−14.9319 ***	−5.3408 **
IAC	−12.5696 ***	−6.0785 **
RF	−24.1457 ***	−4.1222 ***
SR	−9.4475 ***	−4.2760 ***

Note: ** and *** indicate significance at the level of %5 and 1%.

Table 6. Sys GMM regression analysis.

	Direct Impact Models		Moderating Effects Models	
Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**
L.IPU	0.333 ***	0.346 ***	0.155 ***	0.211 ***
	(0.0385)	(0.0282)	(0.0165)	(0.00777)
RF	0.503 **	0.267 **	1.156 ***	1.656 ***
	(0.200)	(0.135)	(0.0739)	(0.0600)
SR	1.609 ***	1.269 ***	1.034 ***	1.027 ***
	(0.112)	(0.0693)	(0.0831)	(0.0398)
PE	2.491 ***		2.482 ***	
	(0.590)		(0.281)	
PE2	−0.000563 ***		−0.000460 ***	
	(0.000197)		(8.80×10^{-5})	
PE*UT			1.429 *	
			(0.736)	
PE2*UT			−0.000492 ***	
			(0.000176)	
IAC		82.48 ***		2.697 *
		(7.645)		(1.429)
IAC2		−0.399 ***		0.130 ***
		(0.0459)		(0.0156)
IAC*UT				78.33 **
				(35.02)
IAC2*UT				−2.064 **
				(0.897)
Constant	6162 ***	5101 ***	8215 ***	5151 ***
	(527.0)	(1626)	(2159)	(1016)
Observations	640	640	640	640
AR(1) test	0.000718	0.000339	0.00129	0.00205
AR1 (*p*-value) test	0.00213	0.00561	0.00444	0.000128
AR(2) test	0.177	0.525	0.131	0.750
AR2 (*p* value) test	0.149	0.226	0.243	0.208
Hansen test	46.18	35.98	25.45	47.71
Hansen (*p*-value) test	0.239	0.194	0.274	0.216
No. of Instruments-j stat.	62	50	44	64
Wald Test-Chi^2	560601	11822	1856	7.350×10^6
Chi^2 (*p*-value) test	0	0	0	0
Number of universities	64	64	64	64

Note: *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.10$. Figure in parentheses (.) indicates robust standard errors.

4.2. Direct Impact of Factors Affecting Innovation Performance

The purpose of this study is to examine the link between the involvement of transnational research collaboration and the innovation performance of universities. Meanwhile, as the key universities policy has been playing a key role in Chinese higher education and innovation development, the study tried to contribute to the examination of its impacts on the transnational research collaboration in Chinese universities. The results of regression analysis on the dynamic panel data of 64 universities directly under the Ministry of Education in 11 years are shown in Table 6, and columns 1 and 2, showing the results of Model 1 and Model 2, respectively, indicate the direct impacts of personnel exchange and international conferences affecting the innovation performance of Chinese universities. In general, all explanatory variables were statistically significant at the 5% level or better. The results show that the impact of personnel involved in international cooperation and exchanges, international conferences, annual research funding, and R&D personnel on the innovation performance of the universities is positive. This means that these factors contribute to improving universities' innovation performance levels.

More specifically, according to the estimated results of Model 1, personnel exchange (PE) in international cooperation has become the primary factor to promote the innovation performance of Chinese universities (IPU), and the estimated coefficient for PE is positive whereas the square of PE is negative, and they are statistically significant at the 1% level. Moreover, using these two coefficients, it can be estimated that IPU reaches the extreme value when PE is 2754, and the extreme value point is within the value range.

These results indicate that there is an inverted U-shaped relationship between PE and IPU. In other words, with the increase in the number of personnel participating in international collaboration, the innovation performance of a university will increase accordingly; when the number of personnel participating in international collaboration exceeds 2754, the innovation performance of a university will decrease with the increase in the number of personnel, as expressed in hypothesis H1a. Since the square coefficient of PE is small, the decline in IPU after the turning point is also small, and the trend is slow.

The impact of international conferences hosted by the university (IAC) on its innovation performance (IPU) is similar. The estimated results of Model 2 show that the estimated coefficient for IAC is positive whereas the square of IAC is negative, and they are statistically significant at the 1% level. Moreover, IPU reaches an extreme value when IAC is 67, which is also within the value range. These results indicate that there is an inverted U-shaped relationship between IAC and IPU. Therefore, when the number of international conferences hosted in one year is less than 67, it will promote a university's innovation performance, and once it exceeds 67, it may inhibit the improvement of a university's innovation performance, as expressed in hypothesis H1b.

The results from the Arellano–Bond test and the Hansen test are also presented in Table 6. The Arellano–Bond AR (1) p-values of the two models are 0.00213 and 0.00561, respectively, which are less than 5%, indicating the autocorrelation and serial correlation in first-order difference. The AR (2) p-values are 0.149 and 0.149, respectively, which are greater than 5%. This means the null hypothesis cannot be rejected, and there is no second-order correlation in the disturbance term. Furthermore, the Hansen test indicates that over-identifying restrictions are valid. The Hansen p-values of the two models are 0.239 and 0.194, which are between 0.10 and 0.25, indicating that there is no over-identification of instrumental variables. The numbers of instruments are 62 and 50, which are less than the number of groups, 64, and fail to reject the null hypothesis. The direct detailed results of Table 5 are reported below in Table 6. According to the descriptive data, most Chinese universities are in the rising stage and have not yet reached an extreme point.

4.3. Moderating Effect of Factors Affecting Innovation Performance

Table 6 also reports the results of the models with multiple interaction terms (Model 3 and Model 4), which indicate the moderating effect on innovation performance and relationships with independent factors. We found that the results are fairly similar, especially regarding the impact of personnel involved in international cooperation and exchanges, international conferences, annual research funding, and R&D personnel on the innovation performance of the universities. In addition, all of these variables are also statistically significant at the conventional level. Nonetheless, the number of international conferences seems slightly responsive to a change in the innovation performance of the universities, as the variable is only statistically significant at the 10% level.

Furthermore, the four interaction terms (PE*UST), (PE2*UT), (IAC*UT), and (IAC2*UT) are also significant at the 5%-or-less level, as shown in Table 5. Column 3 shows the personnel exchange in the international cooperation and university-type interaction term model, which shows the positive and statistically significant impact of personnel exchange and university type. The regression results are shown in column 4 of international conferences' interaction with the moderating variable university type, which also positively impacts the innovation performance of the universities. The estimated results indicate that for different types of universities, the intensity of international cooperation represented by the exchange frequency of international cooperation personnel and the number of international conferences has different effects on the innovation performance level of universities, as expressed in hypotheses H2a and H2b.

In addition, comparing the coefficients of the quadratic term and its interaction term, it can be found that the coefficients of PE2 and PE2*UT are both negative. This means that in first-class universities, the inverted U-shaped relationship between international cooperation personnel exchanges and innovation performance is further strengthened by Haans and Pieters [30], who indicated that the number of personnel exchanges that exceed the extreme point will weaken the innovation performance of first-class universities faster. Conversely, the coefficient of IAC2 is positive and the coefficient of IAC2*UT is negative, indicating that the inverted U-shaped relationship between international conferences and innovation performance is weakened in first-class universities.

According to the regression data, the relationship curve between the number of personnel exchanges in international cooperation and the innovation performance of universities under different types of universities is fitted (Figure 2, left), as well as the relationship curve between the number of international conferences and the innovation performance under different types of universities (Figure 2, right). It can be seen from Figure 2 that, compared with other universities, the innovation performance of first-class universities increases faster with the increase in personnel exchange and international conferences; it can reach a higher extreme value of innovation performance.

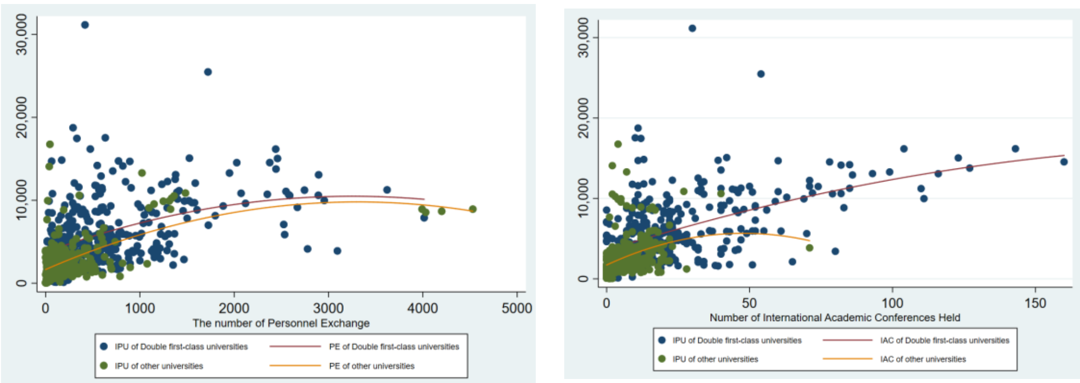

Figure 2. The moderating effect of university type on the relationship between IIC and IPU.

Meanwhile, the model's results show that the AR (1) *p*-value is less than 5%, which indicates that autocorrelation and serial correlation in first-order difference and the AR (2) *p*-value are greater than 5%, which means that the null hypothesis of second-order difference is not accepted as per the established standards as well-reported and recommended by Ulah et al. (2021) [31]. Moreover, the Hansen test indicates that overidentifying restrictions are valid where the Hansen *p*-value supports instrument reliability and fails to reject the null hypothesis. Therefore, system GMM is a valid and excellent technique to apply, as our sample number of cross-sections group "N," 64 countries, is greater than the period "T," which is 11 years in this study, and instruments are less than the number of groups, as per the system GMM-required standards.

5. Discussion and Conclusions

Our study aims to determine the correlation between transnational research collaboration and universities' research performance in China's context. Considering the current regulative environment of the Chinese higher educational system, the study also tried to examine the impacts of the ongoing "Double First-Class Project" on the outcomes of transnational research collaboration in China, which may or may not lead to changes in universities' innovation performance.

In the study, the dependent variables regarding the research and innovation performance of universities include the number of produced academic monographs, the number of published academic articles, and the number of state-funded research projects. The independent variables related to transnational research collaboration activities cover the number of participants involved in international joint research projects and international conferences and the number of international conferences hosted by Chinese universities. The World-Class University Policy is considered a regulating variable, whose impacts are assessed through the amount of research funding received from the state government, local governments, and other related actors. Control factors include the population of full-time researchers and the impacts of the timing (by year) of data collected. Throughout the study, we employed the GMM methods to examine the working hypotheses and a robust check of results with stationary and panel cointegration tests.

The analysis results point to the following three major findings: First, there is a positive correlation between the intensity of transnational research collaboration and the innovation performance of universities. The more actively Chinese universities participate in transnational research collaboration, the more advantageously they perform in the productivity of research and innovation. This echoes previous findings on the positive impacts of international collaboration on organizational innovation performance, such as firms [32], and contributes to the literature with new evidence of Chinese universities.

Second, as the relationship between transnational research cooperation and the innovation performance of Chinese universities is an inverted U-shaped relationship, the correlative growth between both sides will reach its peak at some point and may decline slowly afterward. The analysis found that except for Peking University, Tsinghua Unaiey, and Zhejiang University, whose development is close to the peak point, the majority of Chinese universities are still in the climbing stage of the inverted U-shaped curve. For these universities, at this stage, increasing the intensity of international research cooperation can enhance their innovation performance effectively.

Third, the analysis results reveal a positive moderating impact of the national policy (World-Class University Policy) on the relationship between transitional research collaboration and innovation performance. Particularly, in terms of hosting international conferences, China's world-class policy-funded universities were found to outperform other Chinese universities substantially. Previously, researchers criticized that the world-class university policy in China has been narrowly defined by the Chinese government, which overemphasized the international dimensions rather than national development [33]. To some extent, this study verifies their argument. It, however, presents a bright side of the policy emphasis if one considers Chinese universities' contributions to the global innovation network, global knowledge, and society development positively.

Interestingly, the analysis suggests the impact of increasing the intensity of transnational research collaboration on universities' innovation performance is statically more significant on universities in the list of world-class policy-funded universities. The analysis suggests that these universities have higher performance under the same intensity of international cooperation and can achieve higher performance at the peak point of the inverted-U shape. These universities are usually at the frontier of university rankings and enjoy a higher degree of internationalization. However, this finding does not mean that investment in other universities with lower internationalization should be discouraged. The investment in transnational research collaboration in the universities that are not on the list may receive other payoffs, for instance, in joint educational provisions, which have not yet been covered in this study. Nevertheless, a growing disparity in the performance of research and innovation between the two groups of universities is becoming obvious. In this sense, further efforts would be needed from different stakeholders, including the Chinese government, at different levels and universities, to balance the need of pursuing excellence and equality in knowledge production.

Nevertheless, this study has some limitations. First, the data of the study can be manipulated, thus not revealing the real picture of universities' performance. For instance, the indicator of hosting international conferences is used in the assessment of the implementation of first-class universities' policies in universities. Universities may increase the number of hosting international conferences intentionally to comply with the assessment requirement and neglect other aspects of transnational research collaboration. Panel data documented yearly can also be influenced by data from previous years. Second, in terms of research methods, the measurement of the innovation performance of universities in this study does not consider indicators such as technology transfer, educational provision, or social services, which will limit our knowledge of these aspects. Third, findings on universities that do not receive world-class policy funding are limited. These universities are strategically positioned by the Chinese government in other aspects such as industrial talent provision. The assessment of their innovation performance should also be examined by considering these key aspects, which are not included in this study.

Overall, the study contributes to the literature on universities' innovation performance with new evidence and perspectives. Not focusing on universities, past studies on the innovation of firms already manifested that intensity and diversity of collaboration can have positive impacts on the innovation performance of organizations [34]. This argument has been partly examined by higher education researchers by studying the impacts of increasing the diversity of collaboration between different sectors, i.e., industry–university collaboration [35].

This study sheds light on a new perspective on this investigation by revealing the positive impacts of increasing the intensity of collaboration through transnational research collaboration on universities' innovation performance. It will be interesting for future research to examine the impacts of transnational industry–university research collaboration on universities' innovation performance, as the necessity of developing transnational innovation ecosystems through promoting the synergy between transnational industry cooperation (TIC) and transnational university cooperation (TUC) has already been pointed out in a previous study [36].

Given the above discussion, the study provides solid support for the promotion of transnational innovation ecosystems [36,37]. We should utilize the important role of universities and the positive impacts of transnational research collaboration for the sustainable development of the transnational innovation ecosystem.

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