A Study on the Breadth, Depth and Performance of University-industry Collaboration

Aoqi Xie[1], Shuhan Li[2]

[1]Department of Applied Mathematics, Jilin University, Changchun, 130000, China

[2]Department of Mathematics, Pennsylvania State University, State College, 16801, USA

Keywords: university-industry collaboration; breadth of UIC channels; depth of UIC channels; research performance

Abstract: This paper uses the panel data of 55 universities from 2015 to 2017 in China as research objects to analyze and reveal how university-industry collaboration (UIC) is influenced by its breadth and depth. The Empirical results show: There is an inverted U-shaped relationship between the breadth of UIC channels and the scientific research performance of universities; There is a positive correlation between the depth of UIC channels and the research performance of universities; The depth of industry-university cooperation channels can weaken the inverted U-shaped relationship between breadth and research performance of colleges and universities, making it become a positive correlation. The findings provide a theoretical reference for universities to optimize their collaboration strategy.

1. Introduction

As two basic divisions of society, education and industry have different responsibilities for social development. As an integral part of society, their development should be closely related, instead of being separated.

The Outline of the National Medium- and Long-Term Science and Technology Development Plan (2006-2020) clearly states that present stage emphasizes the promotion of the combination of industry and education, encourages and supports enterprises, universities and research institutes to jointly establish research and development institutions, industrial technology alliance, such as technology innovation system, and regard them as a breakthrough to comprehensively promote the construction of national innovation systems.

In the “Key Points for Work of the Department of Higher Education of the Ministry of Education in 2019”, it is stated that the “Six Excellence and Top Ten” program 2.0 should be fully implemented, which emphasizes that the industry-university cooperation and education project should be used as a platform to bring together 600 enterprises to support 20,000. The project promotes cooperation in running schools, cooperative education, cooperative employment, and cooperative development, and continuously improves the long-term mechanism for the integration of production, and education.

In 1906, American engineer Hermann Schneider first proposed “cooperative education” at the University of Cincinnati, and strongly advocated the cooperation between universities and local enterprises, and cultivated engineering and technical personnel by means of “work-and-learning”. Until the 1980s, industry-university cooperation (UIC) has become a mainstream mode for technological innovation in the world, especially in high-tech fields. It is also a mature experience in the combination of technology and economy in today's economically developed countries.

Although UIC has good traditions and rich experience abroad, the development time in China is not long. In 1992, the State Economic and Trade Commission, the State Education Commission and the Chinese Academy of Sciences jointly organized the implementation of production, research and research projects. Although this has indeed promoted the process of applying the high-tech development of traditional industries in China, it has enhanced the independent innovation capability of enterprises and promoted the transformation of scientific achievements and high-tech

  DOI: 10.25236/ermbfe.2019.011

industrialization. However, whether universities can simultaneously consider “scientific research” and “social services” has been controversial at home and abroad. Whether the current UIC mode will have a negative impact on the scientific research performance of universities is the main problem explored in this paper.

On the one hand, some scholars believe that in the school-enterprise cooperation, enterprises will delay the publication of scientific papers in order to chase commercial profits[1], or the energy of universities will be dispersed[2], which will have a negative impact on scientific research performance. On the other hand, some scholars believe that UIC can not only make breakthroughs in scientific research in universities, but also bring back problems after the results of scientific research are brought into practice, thereby promoting the growth of scientific research performance.[3,4] At the same time, we find that these studies often only refer to the influence of partial conditions on scientific research performance, and cannot describe the overall influence. Therefore, the conclusions are not perfect.

In recent years, scholars have gradually begun to consider multiple UIC channels at the same time to study the impact of their simultaneous effects. For example, Bekkers et al. distinguished several different technology transfer channels between universities and enterprises, and found that, compared with traditional patent sales and licensing and derivative enterprises, universities' more frequent participation channels include consulting and contract research, joint research, and training, etc.[5] Grimpe et al. studied the role of formal and informal channels of UIC in innovation.[6] The whole is closer to the actual study of the relationship between UIC and university research performance.

This paper refers to the research of Laursen and Salter. When analyzing the integrity of UIC channels, the scope and depth of multiple UIC channels are expressed by two basic dimensions: breadth (defined as the number of UIC channels) and depth (defined as the number of in-depth UIC channels).[7,8]

In this paper, 55 research-oriented universities in China from 2015 to 2017 were taken as samples to analyze the impact of the depth and breadth of industry-academic cooperation on the scientific research performance of universities. For analyzing data, we use Stata 14 to do regression and tests. The data we collected in this paper has the characteristics of large cross-section dimension and small-time dimension, so it is short panel data. After running the LR test and Hausman test, random effect model is preferred.

2. Research Hypothesis and Theoretical Analysis

2.1 The breadth of UIC channels influences the scientific research performance of colleges and universities

Due to the diversity of UIC channels, such as consulting, joint research, derivative enterprises, academic BBS and conferences, they all have their own advantages and disadvantages for scientific research in universities. Therefore, dealing with the overall impact of a wide range of cooperation channels is complex. At present, many scholars agree that the access of universities to diversified research resources including enterprise funds has a positive impact on the improvement of their research performance.

For example, 1. Through a variety of channels to cooperate with enterprises, the scope of colleges to acquire and absorb various knowledge and technology has been expanded. Practical knowledge and technology from different companies provide more abundant new elements and new opportunities for university research activities, broaden the innovative ideas of academic research, and thus improve the scientific research performance of universities.[9] 2. While promoting the improvement of university research performance, synergies can be generated between diverse channels of cooperation. For example, formal and informal channels of UIC have shown complementary roles in promoting business innovation,[6] as cooperative participation (eg, collaborative research, research services, staff mobility, and other informal contacts) often precedes or is accompanied by technology transactions (Such as patent transfer and licensing). The former,

as an input element of the latter cooperation channel, promotes enterprise innovation and university research in a collaborative way.[10]

However, some scholars believe that UIC with high cooperation intensity will have a negative impact on the research performance of universities.[11] The first is the increase in the cost of manpower and capital; second, although cooperation improves the level of investment, having partners will increase the cost of the project, because they may find it difficult to work together, thus negatively affecting the research performance.[12]

Therefore, this paper believes that there is a threshold, so that when the scope (broadness) of the industry-university cooperation channel is within this threshold, the impact on scientific research performance is positive, and the influence on scientific research performance changes little or becomes negative with the increase or decrease of the breadth. Because the diversity of channels requires a large amount of manpower and funds to maintain, which increases the cost, and the coordination between different channels becomes more difficult. And fewer channels may not be positive feedback, but instead, increase the burden.

Based on the above analysis, the following hypothesis is proposed:

H1: There is an inverted U-shaped relationship between the breadth of UIC channels and the scientific research performance of universities.

2.2 The depth of UIC channels influences the research performance of universities

The depth of the cooperation channels referred to in this paper is the number of channels for in-depth cooperation between universities and enterprises, reflecting the depth of the channels of cooperation between industry and education. The increase in depth means that universities have produced multiple industry-university cooperation with the same enterprise, or they have produced industry-university cooperation with different enterprises through the same channel. It can be seen that the depth of the UIC channel may have a positive impact on the scientific research performance of universities through two ways. No matter which way, it is necessary to establish deep links between universities and enterprises to increase mutual trust, so as to gain more practical experience and serve scientific research. At the same time, in-depth cooperation between industry and academia can improve the scientific research performance of universities by reducing the marginal cost of universities and enhancing the collaboration between universities and enterprises. In-depth cooperation through a certain channel means that universities have used the same method to carry out cooperation activities with outside companies. This scale effect will share fixed costs and diminish marginal costs.[13] Universities and enterprises carry out in-depth cooperation in the same way for many times, and strengthen their familiarity with each other through long-term run-ins, which can not only reduce the uncertainty of cooperation, but also improve their cooperation ability, so as to help universities find scientific problems in practice and better carry out research.

Thus it can be seen that the increase in the depth of industry-university cooperation channels is conducive to the development of scientific research in universities. Therefore, the following hypothesis is proposed:

H2: there is a positive correlation between the depth of UIC channels and the research performance of universities.

2.3 The depth of the UIC channels regulates the relationship between breadth and university research performance

This paper believes that the depth of UIC channels not only positively affects the research performance of universities, but also weakens the inverted U-shaped relationship between the breadth of UIC channels and the research performance of universities. That is to say, if colleges and universities invest enough time and energy in the existing industry-academic cooperation channels, the diversity of industry-academic cooperation channels will not increase the burden on universities, and even improve the performance of scientific research. As demonstrated in hypothesis H1, there are two main reasons why the increase in the breadth of UIC channels will bring negative effects on the scientific research performance of universities: the increase of cost; the difficulty of coordination between different channels.[14]

According to the hypothesis H2 analysis, when universities make in-depth use of certain channels for UIC activities, the cost will not increase indefinitely, but the scale effect of diminishing marginal cost will occur.[13] If colleges and universities are very familiar with the operation and management of each cooperation channel, they will better coordinate these different cooperation channels and thus produce the synergy effect of "1+1 > 2".[15]

It can be seen that with the deepening of cooperation, the advantages of various channels can be exploited to make up for the deficiencies of other channels, and synergies can be realized in the improvement of scientific research performance. Therefore, the following hypothesis is proposed:

H3: the depth of industry-university cooperation channels can weaken the inverted U-shaped relationship between breadth and research performance of colleges and universities, making it become a positive correlation.

3. Study Design

3.1 Data

The data for this study was derived from multiple databases. 1. "Compilation of Science and Technology Statistics of Colleges and Universities" provides data on scientific research input and output of universities, such as government funding and number of papers published, as well as some data on industry-university cooperation, such as the number of school-enterprise cooperation projects and technology service projects. Quantity, etc. 2. The statistical database of the State Intellectual Property Office provides data on patent activities of the University. 3. China Alumni Association Network (http: / /www.cuaa.net /) published the social reputation scores of colleges and universities over the years, which is mainly obtained by professional institutions to comprehensively assess the social influence of college alumni. In addition, the official website of each university provides relevant information, such as the types of universities. According to the above data sources, 60 universities with relatively complete information from 2015 to 2017 are selected from 76 universities directly under the Ministry of Education, and then non-research universities such as normal universities, arts universities, politics and law universities were excluded, and 165 observation samples from 55 universities from 2015 to 2017 were finally obtained.

3.2 Variables

3.2.1 Dependent Variables

Scientific research performance is measured as the nature log of the number of published papers by universities. The number of published papers is one of the most important indicator of university research performance (Banal-Estaol A, Jofre-Bonet M, Lawson C, 2015)[16], and the logarithmic function to this variable can reduce the effect of outliers. At the same time, the number of invention patent applications and the number of national-level projects were also used as indicators of scientific research performance in the robustness test, and the results were basically the same.

3.2.2 Independent Variables

Breadth and depth are used to represent the diversity and intensity of the UIC channels. Based on existing research and data sources, eight channels are identified including the number of patent licenses, patent sales, technology transfer, number of science and technology service projects, international project collaboration, entrusted development funds, number of partner dispatches, and number of university-controlled listed companies. According to correlation test, multicollinearity does not exist among these variables. We use the median of data to determine if the university participate in each channel per year, the indicator becomes 1 if it participates, and 0 if not. Sum of these eight indicators is the indicator of breadth, the value of the variable breadth spans a range of 0 to 8. Similarly, the average number per channel among there universities is calculated as proxy. If it over average, the depth indicator of that channel becomes 1.

3.2.3 Control Variables

The empirical models include other factors that may affect the research performance, for example, universities with high government funding can perform better in R&D. Therefore, control variables are included in our model, such as government funding, R&D population, and the logarithmic function to these two variables are applied as control variables. The reputation data is collected from Chinese alumni network (cuaa.net), and the variable is in range of 0 to 100. Another control variable is Technology Transfer Office (TTO). The indicator is 1 if there is a national- acknowledged technology transfer institution, and 0 if not. Besides, there are three dummy variables are controlled, which includes university types, region, and year.

To allow for heteroscedastic residuals, standard errors were obtained by the Huber/White sandwich estimator (Wooldridge, 2010)[17]. Because the effects of the independent variables on the dependent variable may be time-lagged, a one-year lag is specified for each control variable. To eliminate a potential bias introduced by outliers, observations for the variables with extreme values lower than the 1% percentile and above the 99% percentile are excluded.

4. Empirical Analysis

4.1 Descriptive statistics and correlation analysis

Table (1) presents the descriptive statistics and correlations of the underlying variables. According to the data, the average breadth of UIC (university–industry collaboration) is 6.94, and the average depth is 3.85, which means the diversity of UIC has reached a certain level, but progression is needed in intensity. Besides, there is a relatively big difference of UIC depth among universities since the standard deviation of depth is 2.13. More than one half of the sampled universities have government recognized technology transfer agencies. As expected, university – industry collaboration performance is positively correlated to both independent variables and control variables, and it has high correlation with R&D population and government funding. However, Variance inflation factors (VIF) were well under commonly accepted limits of 10 for multiple regression models (Neter et al., 1985)[18], so high correlations among these variables will not cause problems of multicollinearity in the estimation.

Table 1 Descriptive statistics and correlatios

Variable	Mean	SD	Min	Max	1	2	3	4	5	6	7
lnrp	8.211293	0.7933463	4.70048	9.604812	1						
Breadth	6.939394	0.8744125	3	8	0.487***	1					
Depth	3.854545	2.136371	0	8	0.591***	0.547***	1				
lnf	13.07046	0.9230455	10.58398	15.00983	0.750***	0.563***	0.586***	1			
lnp	6.595786	0.7342967	4.584968	8.641003	0.777***	0.498***	0.493***	0.758***	1		
reputation	70.16325	8.136496	61.55	100	0.439***	0.350***	0.373***	0.663***	0.546***	1	
TTO	0.746988	0.4360532	0	1	0.434***	0.247***	0.339***	0.467***	0.380***	0.266***	1

4.2 Regression results and analysis

To investigate the effect of UIC breadth and depth on its performance, estimation results of seven distinct models are compared. As shown in table (2), model 1 is basic model and consists of all control variables. From the results, the human resources and government funding are significantly positively correlated with scientific research performance at the level of 0.01, and online reputation and whether universities have nationally recognized technology transfer institutions have no significant impact on scientific research performance. In addition, universities in the north will be slightly weaker than other regions in scientific research.

According to model2 and model3, the results shows that the first degree of breadth is significantly positive, and the second degree is negative, which supports H1: The breadth of university-industry collaboration and the scientific research performance have an inverted U-shaped relationship. In model4 and model5, the sign of squared term of depth is not significant, and the added second degree of depth did not improve the fit of the model based on LLR test. Hence, H2 is supported: The intensity of UIC is significant positively affects university research performance.

The next step is an extension of above models by including UIC depth as a moderator of the effect of UIC breath on research performance. In model6, the added interaction term of depth significantly improves the fit of the model according to the LLR test, and positively moderates the linear effect of UIC breath on research performance. Model 7 is the full model and integrates collaboration depth as a moderator of the nonlinear effect of UIC breadth. In addition, the cross term of the depth and breadth is significantly negative, and the cross term of quadratic breath is significantly positive. Therefore, increasing depth can inverse the U-shaped relationship between breadth and scientific research performance, and there may be an exponential growth trend with very high depth. Thus, support for H3 is provided: UIC depth has a positive moderating effect on UIC breadth.

Table 2 regression results

	model1	model2	model3	model4	model5	model6	model7
Breadth		0.0289735 (0.474)	0.4244413 (0.071)			0.5005257 (0.034)	0.7875044 (0.014)
Breadth^2			-0.0347633 (0.088)			-0.042537 (0.039)	-0.0611825 (0.039)
Depth				0.0261322 (0.095)	0.0329452 (0.556)	0.0307279 (0.051)	2.120206 (0.002)
Depth^2					-0.000891 (0.899)		
Breadth×Depth							-0.5801652 (0.002)
Breadth²×Depth							0.0400721 (0.002)
Res population	0.5493879 (0.000)	0.5471561 (0.000)	0.5294731 (0.000)	0.5429662 (0.000)	0.5418497 (0.000)	0.5184628 (0.000)	0.5093275 (0.000)
Gov Funding	0.2834906 (0.000)	0.2698322 (0.001)	0.2891023 (0.000)	0.2537691 (0.002)	0.252982 (0.002)	0.2639197 (0.001)	0.2573207 (0.001)
TTO	0.1935111 (0.175)	0.1954205(0.172)	0.2044425 (0.159)	0.1934548 (0.168)	0.1931462 (0.168)	0.2056306 (0.149)	0.1812222 (0.192)
Reputation	-0.0041777 (0.146)	-0.0050264 (0.564)	-0.0020444 (0.818)	-0.0040145 (0.638)	-0.0036729 (0.681)	-0.0007023 (0.936)	0.000763 (0.931)
Region(western)							
Region(central)	-0.0478032	-0.0382839	-0.0297941	-0.0471637	-0.0472654	-.0303405	-0.0728972
Region(eastern)	0.0301518	0.0283848	0.0396319	-0.0056226	-0.0055569	0.0018153	-0.0296897
Region(northern)	-0.2799637	-0.2830448	-0.254209	-0.2759808	-0.2780191	-0.2405667	-0.276842
Types	control	control	control	control	control	control	control
Year	control	control	control	control	control	control	control
Constant	1.14976 (0.206)	1.18865 (0.194)	-0.211229 (0.865)	1.485969 (0.106)	1.468952 (0.114)	-0.1478258 (0.904)	-1.117538 (0.378)
Log Likelyhood	-52.951299	-53.054847	-51.634516	-51.910109	-51.902061	-49.724744	-51.590681

5. Conclusion and Insights

This paper takes the panel data of 55 universities in China from 2015 to 2017 as research objects and uses Tobit model to reveal the effects of UIC diversity and intensity on the performance of scientific research, and the moderating effect of depth on breadth. From the theoretical analysis and empirical evidence, the breath of UIC is not the higher the better. Positive effect on research performance is only presented when the diversity is controlled to some certain extent. Additionally, by investigating moderating effects, the study sheds further light on the relationship between UIC intensity and diversity that more benefit can be exploited with increasing the intensity.

This study helps alliance managers to understand how to optimize their collaboration strategy and how to maximize UIC efficacy. One of the main contributions to emphasize the importance of taking into account the deepness of every channel with which university researchers collaborate. Therefore, in the evaluation of research proposals, policy makers and managers of programs may want to not only actively seek cooperation with enterprises when cooperation channels are limited, but also strengthen the established collaboration. In the meantime, universities can increase

investment in research funding and human resources to improve research performance.

Despite its contributions, this study also has certain limitations. Firstly, the number of papers published is applied as indicator for UIC performance, but this does not account for all types of performance. Secondly, there will exist some deviation in the statistical method when calculate depth and breadth. We hope that future research will build on this study to deepen our understanding.

References

[1] Nelson R R. The market economy, and the scientific commons[J]. LEM Papers Series, 2004, 33(3):0-471.

[2] Gulbrandsen M, Smeby J C. Industry funding and university professors' research performance [J]. Research Policy, 2005, 34(6):0-950.

[3] Lee Y S. The Sustainability of University-Industry Research Collaboration: An Empirical Assessment [J]. Journal of Technology Transfer, 2000, 25(2):111-133.

[4] Link A N, Siegel D S, Bozeman B. An empirical analysis of the propensity of academics to engage in informal university technology transfer[J]. Rensselaer Working Papers in Economics, 2007, 16(4):641-655.

[5] Bekkers R, Freitas I M B. Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter?[J]. Research Policy, 2008, 37(10):1837-1853.

[6] Grimpe C , Hussinger K . Resource complementarity and value capture in firm acquisitions: The role of intellectual property rights[J]. Strategic Management Journal, 2014, 35(12):1762-1780.

[7] Laursen K , Salter A . Open for Innovation: The Role of Openness in Explaining Innovation Performance Among U.K. Manufacturing Firms[J]. Strategic Management Journal, 2006, 27(2):131-150.

[8] Wang Y , Hu D , Li W , et al. Collaboration strategies and effects on university research: evidence from Chinese universities[J]. Scientometrics, 2015, 103(2):725-749.

[9] Dutrénit, Gabriela, De Fuentes C , Torres A . Channels of interaction between public research organisations and industry and their benefits: evidence from Mexico[J]. Science & Public Policy, 2012, 37(7):513-526.

[10] Perkmann M , Tartari V , Mckelvey M , et al. Academic engagement and commercialisation: A review of the literature on university–industry relations[J]. Research Policy, 2013, 42(2):423-442.

[11] Rentocchini F , D"Este P , Manjarrés-Henríquez, Liney, et al. The relationship between academic consulting and research performance: Evidence from five Spanish universities[J]. International Journal of Industrial Organization, 2014, 32:70-83.

[12] Albert Banal-Estañol & Inés Macho-Stadler & David Pérez-Castrillo, 2011. "Research output from university-industry collaborative projects," Working Papers 2011/23, Institut d'Economia de Barcelona (IEB).

[13] Pei Zhijun. Social Networks and Economic Development: A Theoretical and Empirical Analysis Based on Social Capital[D]. Zhejiang University, 2010.

[14] Lee S, Bozeman B. The Impact of Research Collaboration on Scientific Productivity[J]. Social Studies of Science, 2005, 35(5):673-702.

[15] ZHOU Zeng – jun, CHEN Jin, MEI Liang et al. The capitalization of S&T achievements mechanism in Chinese research universities[J]. Studies in Science of Science, 2015, 33(11):1641-1650.

[16] Banal - Estaol A,Jofre - Bonet M,Lawson C. The double- edged sword of industry

collaboration: Evidence from engineering academics in the UK [J]. Research Policy, 2015, 44(6): 1160 - 1175

[17] Wooldridge, J. M. 2010. Econometric analysis of cross section and panel data. Cambridge, MA: MIT Press.

[18] Neter, J., Wasserman, W., and Kutner, M. (1985) Applied Linear Statistical Models, 2nd edn. Homewood, IL: Irwin.