

Research on the Relationship between Pure Mathematics and Mathematics Research Level in Institutions Based on ERA and InCites

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Abstract. The main purpose of this study is to explore the internal relationship between pure mathematics and mathematics research level in institutions, utilizing Python to perform correlation analysis in four areas: total number of publications, funding, journals, and cooperative institutions. Besides, Kruskal Wallis test is used for single factor analysis. The findings reveal that the higher the ranking of scientific research institutions, the more positive correlation between the research level of mathematics and pure mathematics. Moreover, the higher the level of mathematics, the greater the impact of the number of pure mathematics publications and the number of international cooperative publications on their mathematics subject ranking. Finally, we offer five practical recommendations for research institutions wishing to improve the level of pure mathematics research.

Keywords: Pure Mathematics; Mathematics; Correlation; Single factor analysis; InCites.

1. Introduction

Mathematics, the science that deals with the logic of shapes, quantities and arrangements, is the cornerstone of everything we do in our daily lives, including mobile devices, computer systems, art, economic activity and more. Mathematics is of great strategic significance to national defense science and technology and national science and technology force reserve[1]. Pure mathematics, as a branch of mathematics specialized in studying mathematics itself rather than for the purpose of practical application, affects the national strength through affecting the overall development of mathematics to a certain extent. Since the 1950s, South Korea has carried out six major reforms in pure mathematics education curriculum[2]. In 2018, The State Council of China issued Several Opinions on Strengthening Basic Science Research in an All-round Way, proposing that we should concentrate on strengthening basic science research and give more priority to key disciplines such as mathematics and physics. The importance of basic subject construction is self-evident.

In recent years, citation statistical analysis based on ESI, InCites and Web of Science(WOS) has gradually attracted the attention of universities all over the world[3]. Yan Ge analyzed and studied the subject influence of Jiangnan University based on InCites and ESI[4]. Wenjing Chu et al. also evaluated the subject strength of materials Science of Jiangxi Normal University based on InCites and WOS[5]. But few have explored the intrinsic relationship between pure mathematics, which is a branch of mathematics, and mathematics. From the naming point of view, the former is the basis of the latter, but how to verify the specific performance of the relationship between the two? What are the influencing factors? How should the importance of the factors be assessed and ranked? Does the study of the relationship between them offer suggestions for the development of mathematics? These are all worth exploring further.

This paper takes Scienccenet.com and InCites database as the main data sources, focuses on Chinese universities and research institutions, and analyzes the relationship between pure

mathematics and mathematics from four aspects: ESI total number of publications, funding, published journals and cooperative institutions. And Kruskal-Wallis test is used to analyze the importance of four indexes in mathematics subject rating. Finally, the conclusion is drawn, and five feasible suggestions are put forward for scientific research institutions that want to realize the development of mathematics discipline.

2. Data Sources and Research Methods

2.1 Data Sources

2.1.1 The analytics tool Incites

InCites is a scientific research evaluation tool based on the collection and analysis of Web of Science (SCIE/SSCI) authoritative citation data. It includes disciplinary, institutional, and worldwide relative evaluation indicators that can track an institution's research output and impact in real time and compare an institution's research performance with that of other institutions and global and subject area averages. InCites offers a variety of subject classification systems, including ESI Classification (22), Web of Science Subject Classification (250+), SCADC in China, ANVUR in Italy, ERA in Australia, FAPESP in Brazil, and OECD. Since there is a clear definition of pure mathematics subject under the Australian ERA classification (pure mathematics is Pure Mathematics, mathematics is Mathematical Sciences), the pure mathematics and mathematical paper data involved in this paper are obtained from InCites based on this classification.

2.1.2 Fund statistics of China Science Net

The National Natural Science Foundation of China (NSFC), as a state-level scientific research fund in the field of natural science in China, plays an important role in the development of the national innovation system. The fund system was established in 1986 to support basic and applied research nationwide, with a focus on supporting innovative research by researchers from universities and research institutions with good research conditions and capabilities. It can be considered that the amount of projects and funds funded by the state is an important indicator to measure the scientific research innovation ability of the school and the importance of the school to scientific research.

2.2 Research Methods

According to the data collected on InCites and NSFC, Excel and Python are used for correlation analysis, Pearson correlation coefficient and Spearman correlation coefficient are used to depict the correlation between them, and outlier analysis is carried out to remove abnormal data. Kruskal-Wallis test is used for single factor analysis.

3. Statistical Data Analysis

3.1 Analysis of ESI total number of publications

Based on the correlation between the total number of publications in mathematics and pure mathematics by each research institution under the Australian ERA classification of InCites, the correlation between pure mathematics and mathematics in the dimension of the number of publications is analyzed. At the same time, Pearson correlation coefficient is used to describe the correlation between the number of mathematical publications and the number of basic mathematical publications (both satisfying normal distribution). According to the number of publications by 11439 mathematical research institutions worldwide (including 1304 mathematical research institutions in China) from 1980 to 2020 according to the Australian ERA classification of InCites, Pearson correlation coefficients of different ranking segments are calculated, as shown in Table 1.

Table 1. The correlation coefficient between pure mathematics and mathematics in the total number of publications

Global ranking segment	Pearson correlation coefficient	China ranking segment	Pearson correlation coefficient
1~100	0.9957	1~100	0.9969
1~200	0.9949	1~200	0.9963
201~400	0.9936	201~400	0.9878
401~600	0.9951	401~600	0.9863
601~800	0.9946	601~800	0.9770
801~1000	0.9962	801~1000	0.9778
1~1000	0.9964	1001~1200	0.8450
1001~2000	0.9967	905~1304	0.9194
2001~3000	0.9972	1~1304	0.9956
3001~4000	0.9962	/	/
4001~5000	0.9957	/	/
5001~6000	0.9904	/	/
6001~7000	0.9833	/	/
7001~8000	0.9612	/	/
8001~9000	0.9501	/	/
9001~10000	0.9256	/	/
10001~11000	0.8883	/	/
11001~11439	0.7951	/	/
1~11439	0.9974	/	/

As can be seen from Table 1, the Pearson correlation coefficient of the number of publications in mathematics and pure mathematics of all institutions is as high as 0.99, no matter in China or globally. This shows on the whole that for scientific research institutions, the number of mathematical publications is closely related to the number of pure mathematical publications, and the two also have a strong linear relationship. Moreover, the correlation coefficient of the top-ranked institutions is larger and stronger than that of the lower-ranked institutions. It is not difficult to show that the top-ranked scientific research institutions with higher mathematics level not only have a high number of mathematical publications, but also have in-depth research in the field of pure mathematics, which also has a high number of publications. In addition, it can be seen more intuitively in China that research institutions with the top ranking in mathematics contribute more to the correlation between the number of publications published in pure mathematics and the number of publications published in mathematics than those with the low ranking.

3.2 Analysis of funded projects(take NSFC as an example)

Eighteen colleges and universities in China whose mathematics subjects are A(including A+, A and A-) in the Fourth Discipline Assessment of China are selected as the research objects. The number of projects and funds in mathematics field and pure mathematics field of these 18 universities from 2000 to 2020 are counted respectively. Pearson correlation coefficient is also used to describe the relationship between pure mathematics and mathematics.

The 18 institutions with an A rating in mathematics are as follows:

A+: Beijing University, Fudan University, Shandong University.

A: Tsinghua University, Beijing Normal University, Nankai University, Shanghai Jiao Tong University, University of Science and Technology of China, Xi'an Jiaotong University.

A-: Jilin University, Harbin Institute of Technology, Tongji University, East China Normal University, Nanjing University, Zhejiang University, Wuhan University, Sun Yat-sen University, and Sichuan University.

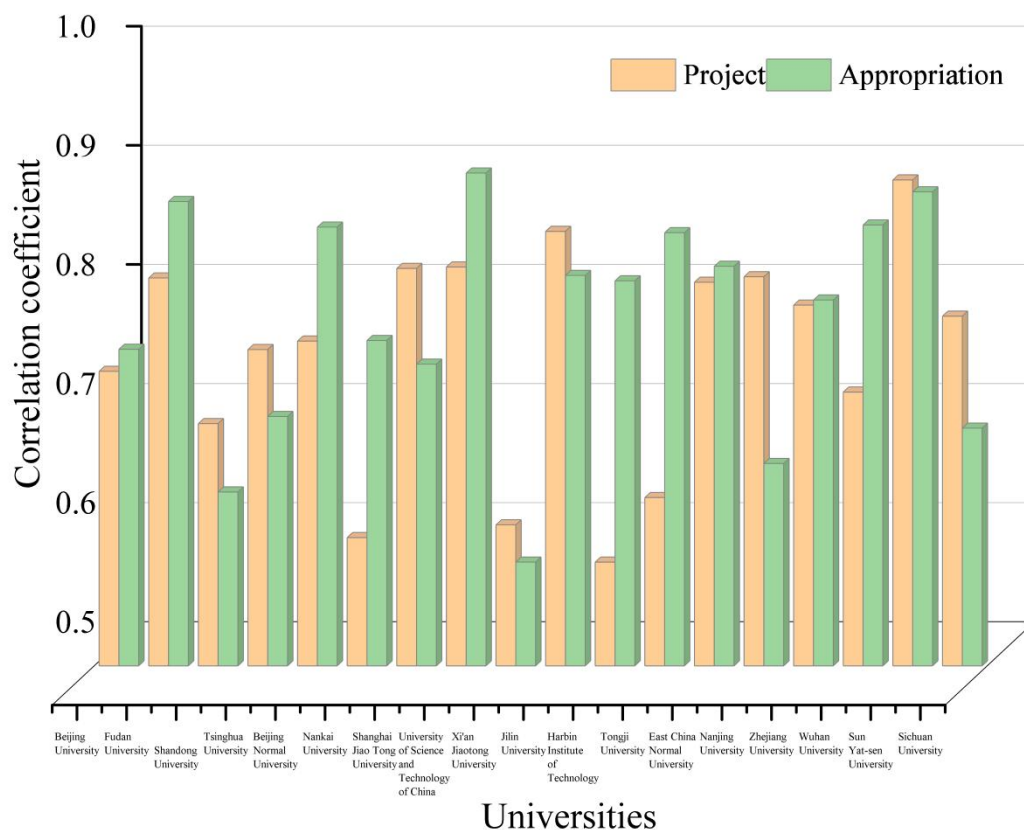


Fig. 1 The correlation coefficient between pure mathematics and mathematics in the fund field of universities

The average Pearson correlation coefficient of the number of pure mathematics and mathematics projects in all universities is 0.7604, while the average Pearson correlation coefficient of the amount of funds is 0.7891, both greater than 0 and closer to 1. This indicates that there is a strong linear correlation between pure mathematics and mathematics among the 18 universities in China with a comprehensive level of mathematics. In other words, these universities not only have a strong overall scientific research strength in mathematics, but also a high level of pure mathematics research and a strong scientific research ability.

In addition, the Pearson correlation coefficient of each university is observed respectively, and it is found that each university has its own advantages. Those with higher ranking in mathematics do not necessarily have more researches on pure mathematics. For example, Sun Yat-sen University, University of Science and Technology of China and Fudan University have the highest correlation coefficient, although their mathematics level is not in the top position. It follows that pure mathematics and mathematics still have a high correlation in the fund field, but the linear correlation is not very obvious.

3.3 Analysis of published journals

In the aspect of published journals, three schools — Peking University, Fudan University and Shandong University, which are rated as A+ in the Fourth Discipline Assessment of China, are selected as the analysis objects. Taking InCites as the data source, this paper screens the published journals of "Australian ERA Classification" Pure Mathematics and mathematical sciences from 1997 to 2020, and uses the periodical impact factor (JIF) of journal citation report (JCR) to evaluate the influence of journals. After the normal test of the original data, it is found that some data do not meet the normal distribution, so Spearman correlation coefficient, which can analyze the correlation of non-normal distribution data, is used in this part of correlation analysis.

From 1997 to 2020, the number of publications published in the mathematics journals of the

three universities shows an overall upward trend, and the number of publications published in Q1 and Q2 also shows an overall upward trend, which also imply the internal relationship between pure mathematics and mathematics, as shown in the following Fig.2. The Spearman correlation coefficients of the three universities are all above 0.8, which shows that the correlation between pure mathematics and mathematics is high in the dimension of published journals. From Fig.3, it can be seen that the number of publications published in Q1 and Q2 journals of pure mathematics of Fudan University accounts for the highest proportion of the number of publications published in mathematics, which is greater than that of Peking University and Shandong universities. This shows that pure mathematics of Fudan University has a great influence on its own mathematics, which is its discipline characteristic. With its outstanding pure mathematics strength, it drives the improvement of its overall mathematics discipline ability to reach the top three levels in China, which further reflects the great promotion of pure mathematics to mathematics discipline. Generally speaking, there exists a very strong positive correlation between pure mathematics and mathematics in the three universities, whether it is Q1,Q2 journals or all journals, which also proves that pure mathematics has a close relationship with mathematics.

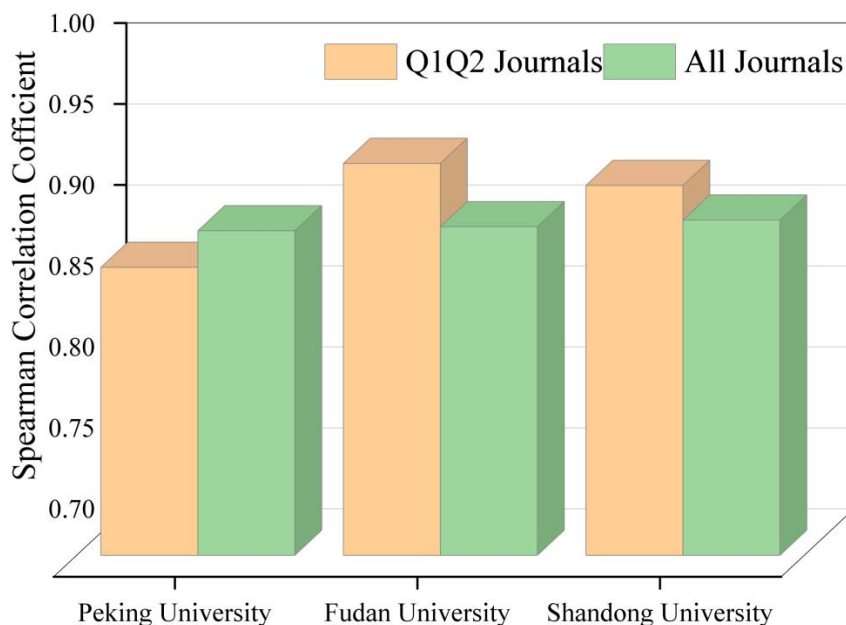


Fig.2. The Spearman correlation coefficient diagram of the number of pure mathematics and mathematics publications in the three universities in Q1Q2 journals and all journals

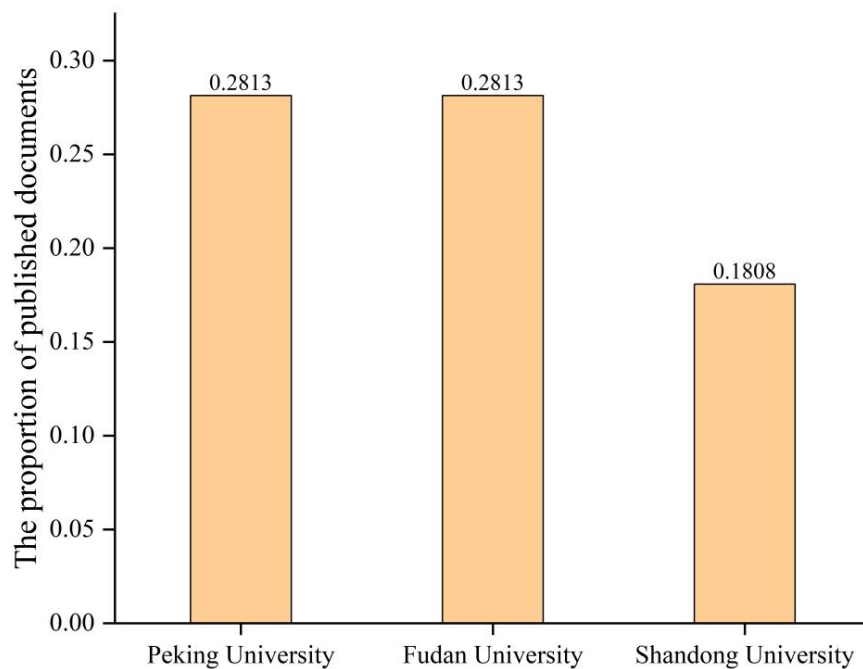


Fig.3. The proportion of publications in Q1Q2 journals of pure mathematics in Q1Q2 journals of mathematics field

3.4 Analysis of cooperative institutions

With the development of "First-class universities and disciplines of the world" construction, universities and institutions are paying more and more attention to improving their own discipline level through domestic and international cooperation. Therefore, by analyzing the dominant disciplines and discipline level of the cooperative institutions, we can indirectly determine whether the two disciplines are relevant. In this section, three representative universities in the field of mathematics in China are selected to analyze both pure mathematics and mathematics level of their cooperative institutions respectively, so as to study the relationship between mathematics and pure mathematics.

Similar to section 3.3, three selected schools are those whose mathematics grade are A+ in the Fourth Discipline Assessment of China: **Peking University, Fudan University and Shandong University**. Then, search their Australian ERA classification on InCites, find the cooperative institutions in the field of mathematics (Mathematical Sciences) from 2016 to 2020, and the top three Chinese and foreign cooperative institutions are selected based on the number of publications published in Q1 journals. In order to better evaluate the pure mathematics level of these cooperative institutions, this paper finds the number of pure mathematics publications published in Q1 journal of the selected institutions to assess the level of pure mathematics. In order to further quantify the level of the pure mathematics of the institution, the data table of the field of pure mathematics (Pure Mathematics) with the number of publications published in Q1 journals is derived in the InCites database, and then the ranking distribution of the six selected institutions in this ranking is calculated through the "vlookup" function in Excel. Data statistics are shown in the following table.

Table 2. The performance of Beijing University's cooperative institutions on mathematics and pure mathematics

Cooperative institution	Number of Q1 journal publications in mathematics	The proportion of Q1 journal publications in mathematics(%)	Number of Q1 journal publications in pure mathematics	The proportion of Q1 journal publications in pure mathematics(%)	The ranking distribution of number of Q1 journal publications in pure mathematics(%)
Chinese Academy of Sciences	579	73.01	19	50	0.30%
University of California System (international)	370	86.45	13	65	0.61%
United States Department of Energy (DOE) (international)	356	89.22	/	/	/
Institute of High Energy Physics, CAS	355	88.75	/	/	/
Centre National de la Recherche Scientifique (CNRS)(international)	354	87.41	12	75	1.52%
Beihang University	335	81.52	5	55.56	5.5%

Table 3. The performance of Fudan University's cooperative institutions on mathematics and pure mathematics

Cooperative institution	Number of Q1 journal publications in mathematics	The proportion of Q1 journal publications in mathematics(%)	Number of Q1 journal publications in pure mathematics	The proportion of Q1 journal publications in pure mathematics(%)	The ranking distribution of number of Q1 journal publications in pure mathematics(%)
Chinese Academy of Sciences	123	60	16	61.54	0.27
University of California System(international)	49	75.38	2	50	13.86
Centre National de la Recherche Scientifique (CNRS)(international)	48	77.42	8	72.73	0.82
Shanghai Jiao Tong University	44	67.69	10	55.56	0.54
United States Department of Energy (DOE)(international)	39	84.78	/	/	/
University of Science & Technology of China, CAS	38	65.52	5	50	2.17

Table 4. The performance of Shandong University's cooperative institutions on mathematics and pure mathematics

Cooperative institution	Number of Q1 journal publications in mathematics	The proportion of Q1 journal publications in mathematics(%)	Number of Q1 journal publications in pure mathematics	The proportion of Q1 journal publications in pure mathematics(%)	The ranking distribution of number of Q1 journal publications in pure mathematics(%)
Chinese Academy of Sciences	283	73.51	5	31.25	0.82
Tsinghua University	237	84.34	0	0	/
University of Science & Technology of China, CAS	233	87.92	/	/	/
Indiana University System(international)	230	88.46	1	100	15.64
Joint Institute for Nuclear Research - Russia(international)	228	88.72	/	/	/
Indiana University Bloomington(international)	227	88.33	1	100	15.64

In the pure mathematics field (Pure Mathematics),when searching in InCites "ERA Classification of Australia" , the number of cooperative institutions of **Peking University**, **Fudan University** and **Shandong University** is 329,368 and 243 respectively. In this paper, they are described as basic data when calculatingrank distribution. Due to the wide audience of pure mathematics and mathematics, cooperative institutions are not necessarily specialized in mathematics, therefore, this paper does not make linear correlation analysis on rankings but only analyzethe ranking distribution. In the field of pure mathematics, the four institutions cooperated with Peking University ranked the top 6%, the five institutions cooperated with Fudan University ranked the top 14%, and the three institutions cooperated with Shandong University ranked the top 16%. Through the calculation we can conclude that institutions with high mathematics level overlap in the cooperative institutions on mathematics and pure mathematics and cooperation publications quality is higher on the whole.Thus, institutions cooperation with high pure mathematics level have a positive role in promoting mathematics research.

In addition, for cooperation in several relatively special data, such as Joint Institute for Nuclear Research - Russia and Institute of High Energy Physics, CAS, they have no relevant data in the field of pure mathematics cooperation, this is because they are targeted scientific research institutions, but this side can reflect that mathematics can promote scientific improvements.

To conclude, from the perspective of cooperative institutions, we can obtain that the institutions with high mathematical level often have a higher level of pure mathematics and are more inclined to conduct mathematics and pure mathematics research at the same time. In addition, institutions with top pure mathematics level are more outstanding on the mathematics contribution, such as Chinese Academy of Sciences and Centre National de la Recherche Scientifique (CNRS), these two institutions' Q1 journal publications ranking are very outstanding, thusinstitutions who research mathematics are more inclined to cooperate with them. From the process of comparative analysis, we can also find that Shandong university's cooperationin the field of pure mathematics is significantly less than Beijing university and Fudan university, and the cooperative output publications published quantity and quality has a lot of progress space, which further demonstrates thatpure mathematics cooperation is importantfor enhancing the level of mathematics discipline.

After the above analysis, in order to provide reasonable and extensive advice to Chinese

institutions about developing mathematics and pure mathematics disciplines, we also statistic the pure mathematics and mathematics cooperation data of Beijing university, Fudan university, Shandong university's 6 cooperative institutions, namely the cooperation international publications proportion from 2016 to 2020.

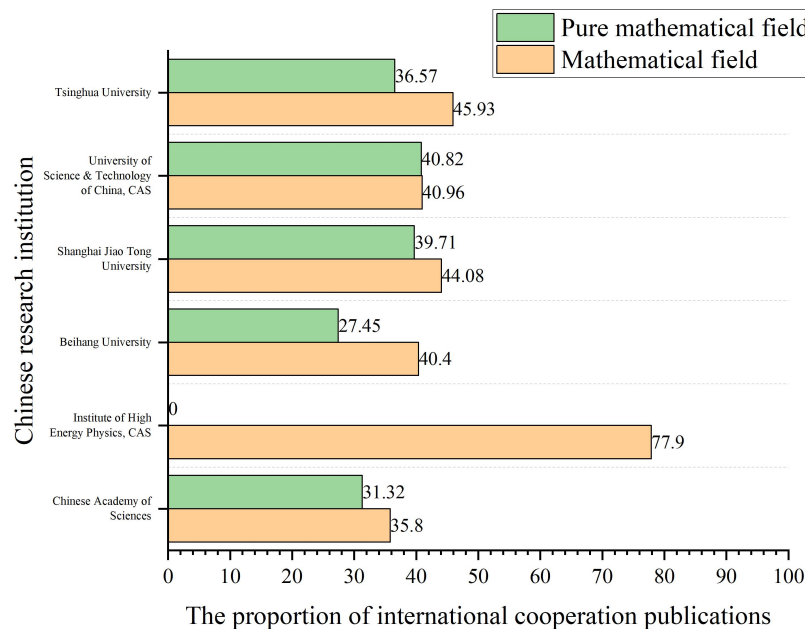


Fig.4. The proportion of international cooperation publications in mathematics and pure mathematics by Chinese institutions

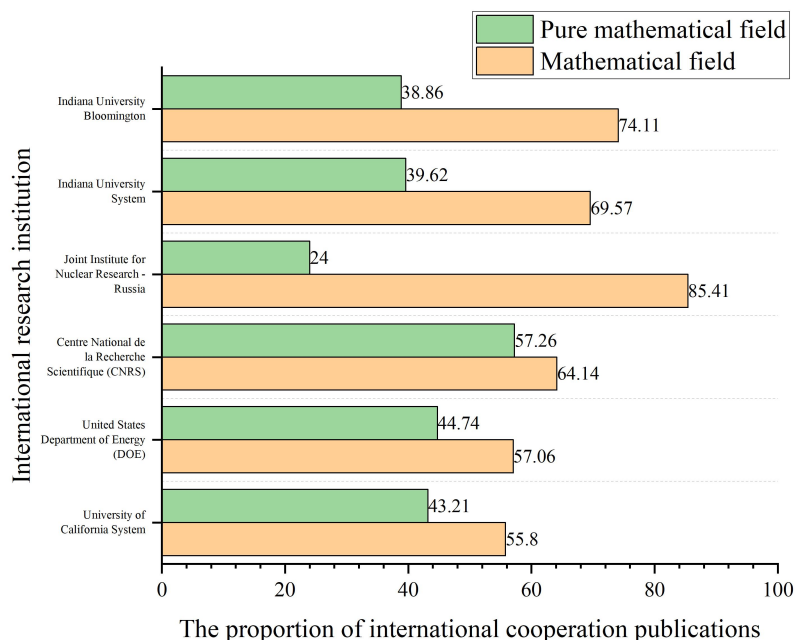


Fig.5. The proportion of international cooperation publications in mathematics and pure mathematics by international institutions

From the above two figures, it is found that the proportion of international cooperation publications of international cooperation institutions is much higher than the Chinese institutions in both mathematics and pure mathematics, and the proportion of international cooperation publications in the field of mathematics of international cooperation institutions is higher than 55%.

The preliminary conclusion is drawn that institutions with outstanding performance in the field of mathematics and pure mathematics often have high data on the proportion of international cooperation publications, and international institutions have better results in this aspect than Chinese institutions.

3.5 Single factor analysis of pure mathematics indexes to mathematics subject rating

The following data are collected from 128 universities in the Fourth Discipline Assessment of China: the total number of publications in Australian ERA classification pure mathematics during 2000-2017, the number of publications in cooperation with domestic or foreign institutions, and the number of publications in Q1 and Q2 journals. This paper uses these four indexes to represent the strength of pure mathematics scientific research in universities, analyzes the relationship between these four indexes and subject rating, and sorts the correlation.

Since continuity variables such as the number of publications does not conform to normal distribution, non-parametric test is used for analysis. Due to the small sample size, the more robust Kruskal-Wallis test is used for statistical inference. The results shows that the total number of published papers in pure mathematics, the number of publications in domestic and foreign institutions, and the number of publications in Q1 and Q2 journals are all related to the subject rating of the university, which has statistical significance ($P < 0.05$). The correlation is ranked as follows: Number of publications in international cooperation of pure mathematics > total number of publications in pure mathematics > Number of publications in domestic cooperation of pure mathematics > number of publications in Q1 and Q2 journals of pure mathematics. (Effect size Cohen's f can represent the size of the correlation, and the larger the value, the more relevant it is)

Table 5. Single factor analysis of the number of four pure mathematical publications in 128 universities

	Total	Q1 and Q2 journals	Domestic cooperation	International cooperation
K-W test statistics	88.271	52.2	83.006	81.732
P	<0.001	<0.001	<0.001	<0.001
Effect size Cohen's f	0.386	0.213	0.348	0.405

Among the four indexes of the number of publications in pure mathematics, the number of international cooperative publications in pure mathematics has a greater impact on the rating of mathematics subjects in universities, and the number of publications in Q1 and Q2 journals has the least impact. This indicates that, on the whole, the exchange status of scientific research projects, international cooperation and mathematics subject rating are closely related, while high-quality publications are not very important to mathematics subject rating.

In addition, we carry out the same analysis for the colleges and universities rated as A, B and C in mathematics subject in the Fourth Discipline Assessment of China respectively, and the results are shown in the table below.

Table 6. Single factor analysis of the number of publications of pure mathematics in universities with different mathematics subject ratings

Cohen's f	Total	Q1 and Q2 journals	Domestic cooperation	International cooperation
A rating	0.3	0.031	0.273	0.283
B rating	0.134	0.064	0.138	0.105
C rating	0.106	0.107	0.092	0.093

As can be seen from Table 6, the stronger the mathematics strength, the greater the impact of the

total number of publications in pure mathematics and domestic and foreign cooperation on the mathematics subject rating. The weaker the mathematics strength, the smaller the correlation between the mathematics subject rating and the indexes of the number of publications in pure mathematics.

4. Conclusions and Suggestions

4.1 Conclusions

Based on the InCites analysis tool, using the methods of correlation analysis and non-parametric test to explore the relationship between pure mathematics and mathematics, the conclusions are as follows:

- From the number of publications published, the higher the ranking of scientific research institutions, the more relevant their mathematical research level is to the pure mathematical research level, especially the Chinese scientific research institutions.
- From the fund support, universities with the leading level in mathematics in China not only attach great importance to mathematics, but also attach great importance to pure mathematics, but each university also has its own unique characteristics of subject development.
- From the published journals, there is a high correlation between the number of publications in pure mathematics and mathematics, and the increase in the number of high-level publications in pure mathematics can give birth to high-level publications in the whole mathematics field.
- From the point of view of cooperative institutions, institutions with high level of mathematics often cooperate with institutions with high level of pure mathematics, and cooperation with institutions with high level of pure mathematics has a positive effect on the research in the field of mathematics. In addition, institutions with outstanding performance in the fields of mathematics and pure mathematics have a high proportion of international cooperation papers.
- From the results of single factor analysis, the total number of publications on pure mathematics and the number of publications in cooperation at home and abroad in universities with high mathematics level have great influence on the subject rating of mathematics, while for universities with low mathematics level, the indexes of the number of publications on pure mathematics have little influence on the subject rating.

On the whole, the development of pure mathematics and mathematics disciplines in China is close, and the development of pure mathematics can effectively promote the progress of mathematics disciplines. However, the close relationship of pure mathematics and mathematics disciplines is very different in different levels of schools. Universities should invest more energy in the research of pure mathematics and attach importance to the role of pure mathematics development in mathematics development.

4.2 Suggestions

- **Increase the research on pure mathematics, so that pure mathematics can drive the development of the whole mathematics discipline.** It is necessary for universities whose mathematics subject needs to be strengthened to take some inclined measures to promote the development of pure mathematics, and must combine theory with practice, instead of focusing only on practice.
- **Select high-quality journals to enhance the level and influence of institutions.** Scientific researchers in institutions should draw more experience and knowledge from Q1 and Q2 journals, and encourage the delivery of journals frequently selected by top institutions when choosing journals to deliver papers.

- **Encourage cooperation with international institutions with strong pure mathematics strength, and at the same time improve the research level of pure mathematics and mathematics in institutions.** Cooperation with international institutions can not only be reflected in international visits and exchanges, but also pay attention to in-depth discussions on thesis writing and academic exchanges. For example, Centre National de la Recherche Scientifique (CNRS) are a good choice.
- **Encourage interdisciplinary research and apply pure mathematics to more disciplines.** The development of interdisciplinary is a hot topic in the research field at present, and interdisciplinary research needs multidisciplinary research foundation, so interdisciplinary research is bound to drive the development of basic disciplines. Strengthening the application of pure mathematics theory in other disciplines can enhance the research of pure mathematics itself.
- **Combining with the actual development situation and the development direction, institutions should take a steady development path of mathematics with their own characteristics.** Research institutions or universities should find out the advantages of two disciplines under their own mathematics discipline, and should focus on highlighting the strengths and strengthening cooperation with other directions to encourage the progress of weak disciplines.

References

- [1] Zhao Jing, Liu Shu.Evaluation of academic performance in mathematics in China [J].Journal of Beijing Normal University(Natural Science),2020,56(04):500-504.
- [2] Lu Shuhuan. The course, trend and enlightenment of Elementary Mathematics Education Curriculum Reform in Korea [J]. Educational Research,1998(10):74-77.
- [3] Wang Li.Identification and Evaluation Methods of Potential Disciplines Based on ESI and InCites[J].Journal of Intelligence,2017,36(02):53-58.
- [4] Ge Y. Analysis and Research on the Influence of University Discipline based on InCites and ESI[C]//2018 8th International Conference on Management, Education and Information (MEICI 2018). Atlantis Press, 2018: 200-204.
- [5] Chu W, Pang H. Analysis on ESI Materials Science and Countermeasure Research Based on InCites and WOS at Normal Universities—Taking Jiangxi Normal University as an Example[C]//2nd International Seminar on Education Research and Social Science (ISERSS 2019). Atlantis Press, 2019: 583-586.