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Evaluation Indicators and Method of Disciplinary Competitiveness of Colleges and Universities: An Example of Peking University

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Abstract: Revealing advantages of disciplines and gaps between one university and others is essential. Although most researchers and institutions are involving evaluation by using various indicators for resulting in the diversified discipline rankings in colleges and universities and for improving education level and enhancing core competitiveness of scientific research. Based on the previous selection standards and evaluation indicators for disciplinary competitiveness and information resources and intelligence analysis being available at the library, the article uses Peking University in this study as a specific case to construct the evaluation system with indicators from six aspects, staff & teams, research output, programs & awards, international cooperation & exchanging, discipline ranking, and innovation ability. The indicators are synthesized to judge the comprehensive competitiveness of universities and their disciplines, and strive to form a reasonable systemic evaluation method and measuring mode so that it can be popularized and used.

Keywords: Disciplinary Competitiveness, Evaluation Indicators, Chinese Universities

1. Introduction

Based on resources of a library, bibliometrics, as a typical tool, could be used to analyze data and evaluate disciplinary competitiveness systematically. On the one hand, it can provide data basis and theoretical support for academic disciplines and promote the formation of diversified investment mechanisms. On the other hand, it can provide decision-making support for the development of academic disciplines, capital investment, and human resource allocation. On the basis of analysis and research, methods of conducting research could be summarized on the evaluation of disciplinary competitiveness in colleges and universities. In addition, a set of reasonable systemic evaluation methods could be achieved as well as the measuring mode, which could be popularized and reused.

The research on disciplinary competitiveness includes the overall ranking of competitiveness and disciplines of colleges and universities, as well as the research on specific databases used by scholars and university libraries, which both involve data sources and evaluation indicators, as well as the specific discussions on research methods.

Following the study on ranking of educational institutions, the ranking of each discipline of *Quacquarelli Symonds World University Ranking* (QS) consists of data from four sources: 1) academic reputation; 2) employer's reputation; 3) citation of all papers; 4) H index. *Academic Ranking of World Universities* (ARWU) selects the total number of the alumni of an institution winning Nobel Prizes and Fields Medals as *Quality of Education*, the total number of the staff of an institution winning Nobel Prizes and Fields Medals and the number of Highly Cited Researchers selected by Clarivate Analytics in each discipline as *Quality of Faculty*, the number of papers published in Nature and Science and the number of papers indexed in Science Citation Index-Expanded (SCIE) and Social Science Citation Index (SSCI) as *Research Output*, and Per capita academic performance of an institution as *Per Capita Performance* to rank the world universities in its evaluation system. Wang Jimin, a professor at Department of Information Management of Peking University, has conducted a quantitative analysis on related data of 17 primary disciplines in China's humanities and social sciences during

the past 10 years based on the standardized data of Peking University's primary discipline data analysis platform (http://scie.pku.edu.cn), including discipline ranking, national social science funds, papers with international collaboration, core domestic Chinese journal articles, national outstanding doctoral theses, outstanding achievements of colleges and universities, key disciplines, key research bases of the Ministry of Education, and outstanding talents.

Judging from the scholarly research on the disciplinary competitiveness of colleges and universities, Zhu used Jinan University as an example to analyze its development trend of scientific research output of 18 disciplines and the competitive advantages compared to the other four universities in Jinan City, and categorized the competitiveness of each discipline. The data source was limited to SCIE, and the number of papers included in SCIE was the only indicator [1]. Zhou and Hua used bibliometrics to analyze papers hosted or jointly written by Chinese scholars published in Nature and Science from various angles of these papers, such as quantities, types, core authors, collaboration countries and institutions, and citations [2]. Li and Zhou used Xi'an Jiaotong University as an example and used InCites and Essential Science Indicators (ESI) databases as the data sources to statistically analyze research competitiveness indicators, such as paper output, influence, ESI dominant subjects, and frequently cited papers [3]. Xu took SCI papers of the national key laboratory of optoelectronic materials and technology of Sun Yat-sen University as an example to evaluate the number and quality of laboratory papers, research direction, international cooperation, and international influence, and compared it with the national key laboratories of optoelectronic materials in other universities [4]. Liu analyzed research performances of 11 top world universities, including the top five universities in China and other countries and the top university in Asia [5]. Zhou used SciVal Spotlight to analyze the competitive advantage of Nankai University [6]. Zhao *et al* selected the SCI, SSCI, and A&HCI databases of Web of Science (WOS) database and Chinese papers of Peking University published in Chinese National Knowledge Infrastructure (CNKI) from 2003 to 2012 as the main data source and analyzed the scientific research competitiveness by bibliometrics [7].

Based on those of previous research on the disciplinary competitiveness of various universities, Peking University Library conducted a quantitative evaluation on the scientific research strength of Peking University's academic papers in 2011 and completed the *Analysis Report of Research Strength of Peking University* [8]. In the first National University Library Service Innovation Contest and Seminar, many entries were related to the disciplinary competitiveness. For example, Fudan University Library analyzed the academic competitiveness, research hotspot analysis, and scientific research ability evaluation of disciplines for mathematics and physics in 2013 [9]. Moreover, Huazhong Normal University made many achievements based on the measurement of incitation of the output of the Chinese journals of the liberal arts teachers to the establishment of the database of teaching and research performance of the teachers [10].

From the perspective of data sources, ESI offers the major data. The main reason is the standardized and complete data, including various determinant indicators and international annual threshold for each discipline [11]. The major criticism on it is its simple database, especially because it rarely evaluates the humanities and social sciences. Thus, fully showing the research strength of China's scientific research institutions is impossible.

From the perspective of evaluation indicators, they are not only the absolute indicators of scientific research output but also the relative impact indicators to determine global influence. Scientific research competitiveness should be composed of scientific research productivity, scientific research influence, scientific research innovation, and scientific research development [12]. Based on four dimensions of topics, papers, patents, and scientific research achievements, Wang evaluated research competitiveness of 141 civilian-run regular colleges and universities and 275 non-government funded undergraduate independent institutes in China [13]. Deng's evaluation on the research competitiveness in the philosophy and social sciences departments of universities followed this basis, in addition to two indicators, namely, the monographs and the research reports submitted to the relevant departments [14]. Li *et al* proposed innovation of the university discipline competitiveness under the background of Double First-Rate from three aspects, such as academic teams, scientific research, and teaching outcomes [15]. Qiu and Ou used the quantity of papers included by ESI database indicating scientific research productivity and the quantity of patent of invention indicating scientific research creativity in research competitiveness evaluation [16].

From the perspective of research methodologies, most of the studies focus on the comparative analysis of InCites and other bibliometric tools and the evaluation research of F1000, ESI, Spotlight, cited motivation analysis, peer review, and other bibliometrics [17-21]. In addition, some studies focus on the performance analysis of scientific research competitiveness of universities based on the analytical hierarchy process and data envelopment analysis [22].

Overall, the evaluation system of disciplinary competitiveness is increasingly improved, and data sources are increasingly diversified, resulting in the diversified discipline rankings in colleges and universities. University libraries should strengthen their cooperation with decision-making departments based on their own resource advantages and disciplinary characteristics in their universities to complete a comprehensive, structured, and systematic evaluation report of disciplinary competitiveness by comprehensive and diversified evaluation index systems.

2. Evaluation of Discipline Competitiveness

The purpose of constructing an evaluation index system of disciplinary competitiveness is to explore advantages of

disciplines and gaps between one university and others and to enhance the library's important role in decision-making and strategic positioning of disciplines in colleges and universities, with the advantage of information resources and intelligence analysis of libraries. 44 national primary doctoral disciplines are selected from five departments of Peking University (for example, Division of Science, Division of Information & Engineering Science, Division of Humanities, Division of Social Sciences, and Division of Economics and Management) for literature review and quantitative analysis. Moreover, according to the status and trends of these disciplines, strengths and weaknesses of them are evaluated. Data support and suggestions are provided as well for disciplinary development and construction, funding investment, and building world-class disciplines of Peking University. The evaluation steps included the selection of evaluation object, evaluation content and emphasis, evaluation index system, and methods of evaluation and judgment are as follows.

2.1. Selection of Evaluation Object

According to latest rankings like ARWU, QS, US News World University Rankings, and Times Higher Education World University Rankings, all the rankings are averaged and the comprehensive ranking of universities could be obtained. Considering the regional attributes, the top 2 universities are respectively selected in the United States, the United Kingdom, Canada, Hong Kong, China, and other Asian countries. Meanwhile, to emphasize the competitiveness of Peking University in the humanities and social sciences, *2012 Academic Evaluation Results* of Chinese Ministry of Education, and *2016 China University Evaluation Research Repor*t published by iResearch China Alumni Association Network (www.cuaa.net) are used as references. Six universities, namely, Fudan University, Renmin University of China, Wuhan University, Zhejiang University, Sun Yat-sen University, and Nanjing University were selected for benchmarking analysis. Therefore, the research participants have covered 18 colleges and universities. In addition to the six ones above, Harvard University, MIT, Stanford University, Cambridge University, Oxford University, University of Toronto, University of Tokyo, National University of Singapore, University of Hong Kong, Chinese University of Hong Kong, Peking University, and Tsinghua University should be included. When selecting the reference institutions for other universities, a certain number of different institutions can be chosen for comparative research based on their own development goals and disciplinary characteristics.

At the same time, for the competitiveness analysis of the disciplines, their ranks among Chinese Ministry of Education must be considered as the basis of choosing the corresponding comparison institutions, and then conduct data analysis and comparison to find the gap between Peking University and other top-ranking institutions.

2.2. Data Source

In the big data era, the analysis of disciplinary competitiveness cannot be limited to the simple data analysis of the database. The library's abundant information resources should be used, and the multiple data sources and diversified indicator systems from the Internet should be also applied. This study and evaluation of the disciplinary competitiveness not only combines CNKI (i.e. papers only indexed in CSSCI and A *GUIDE TO THE CORE JOURNALS OF CHINA* by Peking University Library (PKUCJ)), Web of Science (only papers indexed in SCI, SSCI, A&HCI), SCOPUS database and the patent data of Innography, but also involves the data of official websites of National Natural Science Foundation of China, *National* Planning *Office of* Philosophy and Social Science of China, Chinese Ministry of Education, Chinese Ministry of Science and Technology, the Chinese Academy of Sciences, the Chinese Academy of Engineering and many colleges and universities.

The paper uses InCites, SciVal, ESI, TDA, Innography and MS Excel, SPSS, Tableau and other analysis softwares for comprehensive interpretation, the data are objective, comprehensive and substantial. In addition, the paper aims at many specific and key disciplines supported and developed by Peking University but not every discipline. Therefore, the conclusions are feasible for most academic departments.

2.3. Evaluation Index System

The indicators of disciplinary competitiveness should not only demonstrate the scientific research performance of scientific research institutions but should also reveal research development, potentialities, and trend of these institutions. The paper focuses on staff & teams, research output, research projects & awards, international cooperation & exchanging, discipline ranking, and innovation ability, and sets the secondary and tertiary index systems. The evaluation indicators of science and engineering is slightly different from that of humanities and social sciences, and some disciplines have their own specific indices.

As shown in Table 1, full-time faculties, high-level specialists, and key laboratories or research bases are important foundations for discipline construction and personnel training, and also reflect the research strength and core competitiveness of a university. This study collects the number of full-time faculties and the information of high-level experts, including academicians of the Chinese Academy of Sciences, academicians of the Chinese Academy of Engineering, Changjiang Scholars, Distinguished Young Scholars of the National Science Foundation, Excellent Youth Scholars of the National Science Foundation, senior professors, as well as the number of national key laboratories, the key research base of the humanities and social sciences of the Ministry of Education as judgment indices of scientific research.

Research output is determined by the publication of academic papers and award-winning monographs. The papers are those cited by indexed in SCIE, SSCI, and Arts & Humanities Citation Index (A&HCI), and those cited by CSSCI and PKUCJ in WOS, SCOPUS or CNKI, including the number of papers, cited papers, citation impact of papers in

field, and H index, and highly cited papers and hot papers in WOS. The studies should be the important scientific research achievement in the humanities and social sciences. This paper chooses the award-winning works of the outstanding scientific research achievement award (humanities and social sciences) by the Ministry of Education.

Considering research projects & awards, this paper believes that the number of projects funded by the State and the Ministry of Education reflects the advantage of basic research and applied research of one university to some extent. Funds are classified according to Major Program, Key Program, General Program, and Youth Program, and also consider the number of faculty members and the number of funds. This study also involves some famous national awards, such as National Natural Science Awards, National Technology Invention Awards, National S&T Progress Awards, and the Ho Levng Ho Lee Fundation. Furthermore, diversified awards are given in each discipline, which is also a key performance indicator of research competitiveness, like Sun Ye Fang's Economic Science Award, Chen Shengshen prize in Mathematics, Hua Luogeng prize in Mathematics, Chinese Medical Science Prize, World Habitat Award, and so on.

International collaborative papers in WOS and SCOPUS, cooperative institutions and international students judge international cooperation and exchanges. The index of collaborative papers is calculated by the number of papers that contain one or more international co-authors. The index of discipline ranking is determined by international disciplinary ranking, like QS and ARWU, and whether or not being top 1% or 0.1% in ESI or national level key discipline by Chinese Ministry of Education. The innovation performance is determined by the number of application and grant of patents and the number of high-strength patents in this discipline.

Table 1. *Evaluation index system of disciplinary competitiveness.*

Primary indices	Secondary indices	Tertiary indices
Staff & Teams	staff	Full-time faculty members in field
	High-level specialist	Members of the Chinese Academy of Science in field
		Members of the Chinese Academy of Engineering in field
		Distinguished Young Scholars of the National Science Foundation in field
		Excellent Youth Scholars of the National Science Foundation in field
		Changjiang Scholars in field
		senior professors in field, especially in some humanity sciences
	Key laboratories & bases	National Key laboratories for sciences, and research bases for social sciences
Research Output	Academic papers	Numbers, citation impact, H index of papers cited by SCI, SSCI and A&HCI
		Numbers, citation impact, H index of Chinese Papers cited by CSSCI and PKUCJ
		Highly cited papers in WOS
	Award-winning monographs	Outstanding achievement award of scientific research in Colleges and Universities by the Ministry of Education
Programs & Awards	Programs	National Natural Science Foundation of China in field
		National Social Science Foundation of China in field
		Humanities and Social Science project of Chinese Ministry of education in field
	Research awards	National Natural Science Awards
		National Technology Invention Awards
		National S&T Progress Awards
		The Ho Levng Ho Lee Foundation
		Some special awards in field, such as Sun Ye Fang's Economic Science Award, Chen Shengshen prize in Mathematics, Hua Luogeng prize in Mathematics, Chinese Medical Science Prize, World Habitat Award, and so on
International Cooperation & Exchanging	International cooperation	Number and citation impact of papers having international co-authors in WOS and SCOPUS
		Collaborations with international organization in papers in WOS and SCOPUS
	International exchanging	Numbers of international students per year in field
Discipline Ranking	Discipline ranking	Discipline ranking in QS & ARWU
	First-level discipline	Whether or not being top 1% or 0.1% in ESI
		Whether or not being national key discipline
Innovation Ability	Performance of patent	application and grant of patents
		Number of high-strength patents

2.4. Methodology

2.4.1. Evaluation of Comprehensive Competitiveness of Colleges and Universities

The evaluation of comprehensive scientific research competitiveness between Peking University and other universities is based on the indicators in Table 1. This study analyzes and compares these tertiary indicators included. Based on the performance of papers, innovation ability, international cooperation & exchange and discipline ranking, this paper conducts a comparative analysis on these universities both home and abroad, and compares all indexes of the selected seven universities in China mainland. Moreover, this study comprehensively evaluates multiple indicators, obtains the comprehensive scores, and finds the gap between Peking University and other universities.

The basic model of multi-index comprehensive evaluation is as follows:

Firstly, this paper builds the original statistical data matrix V in Equation (1), where i is the institute No. (i=1,2,3 …I), and j is the index No. (j=1,2,3….J).

$$V = \begin{bmatrix} v_{11} & \cdots & v_{1J} \\ \vdots & \ddots & \vdots \\ v_{I1} & \cdots & v_{IJ} \end{bmatrix} \quad (1)$$

Secondly, this article converts the statistical data into the dependency matrix C_{ij}. The dependency degree of the jth indicator of the ith mechanism is defined as $C_{ij} = v_{ij} / \bigvee_{i=1}^{I}(v_{ij})$, where the denominator $\bigvee_{i=1}^{I}(v_{ij})$ represents that in the J indicator statistics, and the maximum value is the denominator.

After the conversion, the evaluation matrix C is obtained in Equation (2):

$$C = \begin{bmatrix} c_{11} & \cdots & c_{1J} \\ \vdots & \ddots & \vdots \\ c_{I1} & \cdots & c_{IJ} \end{bmatrix} \quad (2)$$

Thirdly, the paper engages the opinions of experts, determines the weight of each indicator, and forms a weight vector in Equation (3).

$$B = (b_1, b_2, \cdots, b_J), \sum_{j=1}^{J} b_j = 1 \quad (3)$$

Fourthly, weighted average of evaluation matrix is followed in Equation (4). This study obtains a table of dependency degree of comprehensive evaluation and arranges these evaluated colleges and universities in descending order of dependency degree to obtain a scoring sheet of overall competitiveness evaluation for quantitative statistics.

$$A = B \times C^T = (b_1, b_2, \cdots, b_J) \begin{bmatrix} c_{11} & \cdots & c_{1J} \\ \vdots & \ddots & \vdots \\ c_{I1} & \cdots & c_{IJ} \end{bmatrix}^T = (a_1, a_2, \cdots, a_J) \quad (4)$$

2.4.2. Evaluation of Comprehensive Competitiveness of Disciplines

Substantial differences are found in the development level of various disciplines among different universities. At the beginning of the evaluation of research competitiveness in various disciplines, this study should select the benchmarking institutions based on disciplinary ranks but not universities' ranking. The same benchmarking institutions are not suitable for different disciplines. The overseas universities should be selected based on the international ranking of each discipline, and the domestic universities should be selected based on the discipline evaluation of domestic ministries of education.

The characteristics of different disciplines are different. When this study assigns weights of indicators in different disciplines, experts' opinions are the major references. For example, papers indexed in SSCI, CSSCI and PKUCJ should be given higher weights in humanities and social sciences, while papers indexed in SCI should be given a higher weight in science and engineering disciplines. A certain difference is found between the index system of scientific research competitiveness evaluation of various disciplines and the comprehensive competitiveness evaluation of universities. Moderate reduction or deletion of certain indicators is more helpful to various disciplines.

To evaluate disciplinary competitiveness, the study should not only compare and identify the achievements of one discipline in the past but predict and plan the potential and trends of the discipline in the future. Thus, the study will also evaluate the annual changes of indicators and use tools such as system dynamics to analyze and predict the tendency.

2.4.3. In-depth Analysis of Disciplines of Peking University

In addition to the threshold analysis of Peking University and other universities, to conduct a thorough internal analysis of Peking University itself is critical, which will be effective to reveal the disciplinary development of Peking University and to provide the feasible and suitable methods for Peking University's construction of first-grade university and first-grade disciplines.

The development of each discipline of one university does not depend entirely on the contribution of only one department, but on efforts of multiple departments jointly. For example, chemistry of Peking University's being top 0.1% ranking of ESI lies in efforts of researchers from College of Chemistry and Molecular Engineering, School of Life Science, School of Engineering, School of Physics, and the Faculty of Medicine, and other departments. In *Chemistry Competitiveness Analysis Report of Peking University*, the study analyze the authors' affiliation with papers published by Peking University, and calculate their respective contributions.

This study uses highly cited papers, hot papers and authoritative journal articles to identify outstanding researchers of various disciplines to position outputs of their superior talents and first-class academic researchers. Based on the existing research directions, this study will identify the orientation for potential frontiers, understand the research status of Peking University in some frontier fields and the similarity with international ones. The study analyzes papers of Peking University's scholars who have collaborations with international organizations, identifies and selects effective international partners by the number of cited papers, highly cited papers and hot papers, and then strengthens the international cooperation in future. For the key laboratories of each discipline, WOS should be used to identify the key laboratory papers, analyze their scientific performance and international influence, and conduct a comparison with other laboratories in the corresponding field.

3. Discussions

Due to the limitation of data availability and the complexity of the problem, there are some threatens to the validity of this study. Feasible solutions are prompted up for the future studies.

3.1. Data Download and Cleaning Process

When downloading data from WOS database, the study should search for documents by organization-enhanced to ensure that papers of one organization can be found as completely as possible without omissions. Because some papers have hundreds of co-authors, data of them will be missing when being opened in MS Excel or Access. However, the integrity of information should be guaranteed when WPS is used to open files of Excel or Access. In addition, discipline matching is incomplete for some papers in WOS, so that this study must provide the information of disciplinary classification for them.

When downloading data in Scopus database, documents should be searched for by affiliation for complete documents of one organization and use Scopus affiliation identifier to select all sub-affiliations from results of potential affiliation matches.

When downloading data from CNKI database, this study can get information of citation times and downloaded times of papers in webpage format, as well as authors' affiliations and funding information in export format. The study should copy the former in MS Excel and match with the latter according to the titles of papers. While downloading data from institutions, priority publications, and some un-useful papers, such as announcements, awards, obituaries, admission brochures, celebration announcements, notices, exhibitions, and advertisements should be removed.

3.2. Discipline Matching and Attribution of Cross-Database Data

Data of disciplinary competitiveness analysis report comes from a large number of databases. Many problems exist in the disciplinary classification, because each database has its own independent disciplinary classification system, and many differences exist in disciplinary development and professional setting in colleges and universities of all over the world. This study conducts a comparative analysis under the same discipline system. Given that the accurate mapping is essential to the accuracy and persuasiveness of academic competitiveness analysis, here this study starts from the research content and uses the disciplinary classification system of the Ministry of Education, supplemented by the keyword retrieval of the paper, thereby establishing a one-to-one correspondence between each database and the analyzed subject.

3.3. Complex Data Information and Visual Display

This paper involves many disciplines and evaluation indicators. It cannot meet the needs of research and complex data information is difficult to display in an orderly and regular manner, with simple histograms, line graphs, scatter diagrams, bubble diagrams, radar maps, and so on. The study uses a multi-indicator fusion analysis and integrate the multiple indicators into one graph for ingenious visual display, such as graphics of index value, graphics of index, graphics of index relation, visualization of time and space, conceptual conversion of data, and display of dynamic charts.

4. Conclusion

The purpose of evaluating and analyzing the competitiveness of colleges and universities is not to classify the various institutions, but to enhance the disadvantaged *disciplines* by learning dominant disciplines of other universities rather than exaggerating dominant disciplines by comparing with disadvantaged disciplines of other universities. Therefore, to evaluate the discipline competitiveness, the study should not only analyze the annual change and horizontal comparativeness from the number of studies but also understand the trend of scientific research in various disciplines and the gap with other universities and/or institutions from the macro-level. Finally, the literature-based content should be analyzed, such as keywords, to explore the similarities of research between Peking University and the international fronts, and to help scientific research institutions select good international partners and help them to find ways to rapidly improve their international influence.

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