

Retraction

Retracted: Influencing Factors of University Core Competence: An Empirical Study Based on the Entropy Weight Gray Relation Model

Discrete Dynamics in Nature and Society

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] Y. Shi and X. Yang, "Influencing Factors of University Core Competence: An Empirical Study Based on the Entropy Weight Gray Relation Model," *Discrete Dynamics in Nature and Society*, vol. 2021, Article ID 8724591, 10 pages, 2021.

Research Article

Influencing Factors of University Core Competence: An Empirical Study Based on the Entropy Weight Gray Relation Model

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To measure the gray relation between the core competence of research universities and its influencing factors, this paper took the same period statistical data of the five research universities directly subordinate to the Ministry of Education of China as the research samples, all these five schools were shortlisted in the “World Top 300” rankings of USNews, QS, THE, and ARWU from 2014 to 2018, and the indicator systems of the four authoritative lists were taken as the basis; 30 representative indicators affecting the core competence of research universities were selected, and the gray relation model was adopted for the research; moreover, this paper applied the information entropy method to calculate the weight of each indicator and estimate the comprehensive gray relation between the core competence of research universities and the entire factor system. This research gives the rankings of the influencing factors of the core competence of research universities, and there is a 0.8485 degree comprehensive gray relation between the influencing factors and the core competence of research universities, which has further clarified the future development direction of research universities.

1. Introduction

In recent years, countries around the world have realized that “whether a country has world-class universities is not only an important measure of the development level of a country’s higher education but also an important manifestation and development appeal of the country’s comprehensive national strength in terms of science, technology, and economy [1].” As a result, some countries have actively implemented a series of “world-class” strategies, such as Germany’s “Elite University Project” (2005) (Exzellenzinitiative) [2], South Korea’s “WCU Project” (2008) [3], Russia’s “5–100 Project” (2013) [4], Japan’s “Global Top University Program” (2014) [5], and India’s “Institutional Excellence Program” (2017) [6].

On September 20, 2017, the Ministry of Education of China, the Ministry of Finance of China, and the National Development and Reform Commission jointly issued the Notice on the Announcement of Construction Lists of First-

Class Universities and First-Class Disciplines [7], which has determined the name list of Chinese universities to be constructed into world-class universities. So far, the “double first-class” construction strategy, another major education strategy besides “211” and “985” strategies, has been carried out rapidly in colleges and universities within the country. On August 8, 2018, the Guiding Opinions on Accelerating the Construction of “Double First-Class” Universities was issued [8], which provided an all-around guidance for the construction of “double first-class” universities and promoted the construction process to enter a substantive progress stage. On March 13, 2021, China put forward new requirements on higher education development in the Outline of the People’s Republic of China 14th Five-Year Plan (2021–2025) for National Economic and Social Development and Long-Range Objectives for 2035. On the “double first-class” universities, the Outline suggests building first-class universities and first-class disciplines separately and supporting the development of high-level

research universities. As the objects of “double first-class” construction, the clarity of the core competence of research universities and the quality of construction are related to the structure of the value chain and its evolution and connected with the Chinese Dream of the rejuvenation of the Chinese nation. Specifically, in terms of talent training, research universities are responsible for cultivating high-quality, excellent, and professional technical talents and high-end outstanding talents, which are urgently needed for China’s social progress and economic growth. In terms of scientific research, research universities lead knowledge innovation, drive scientific innovation, and empower the integrated and collaborative innovation between teachers, learners, researchers, and industry practitioners. In terms of social services, research universities undertake the major mission of satisfying social needs, facilitating national strategies, and building a community with a shared future for mankind. Overall, research universities play a decisive role in enhancing China’s advantages in the increasingly fierce global competition in economy, science, and culture.

However, from the perspective of theoretical research, there are few literatures focusing on the core competence of research universities, and the existing ones are mostly qualitative and macroanalysis of some domestic scholars, such as Wei and Zheng [9] and Zhang et al. [10], and the quantitative analysis is almost blank; from the perspective of practical operation, there are still problems such as unclear connotation and inadequate evaluation [11], which have limited the process of the “double first-class” construction to a certain extent. In view of this, this study draws on the four rankings of US News Best Global Universities (hereinafter referred to as USNews), QS World University Rankings (hereinafter referred to as QS), THE World University Rankings (hereinafter referred to as THE), and Academic Ranking of World Universities (hereinafter referred to as ARWU), combining with the statistical data of five research universities directly subordinate to the Ministry of Education of China over the years, and it attempts to explore the influencing factors of the core competence of research universities and the differences in their influence degrees, in the hopes of providing a reference for further clarifying the construction direction of research universities and the promotion of “double first-class” construction.

2. Current Development Status of Core Competence of Research Universities

The term “core competence” was originated from the field of corporate strategic management, and it refers to the unique capabilities and resources of the enterprises formed during the operation process, which enable the enterprises to have sustainable and comprehensive advantages that can hardly be imitated by their competitors in terms of technology, products, management, and culture [12, 13]. Later, some scholars grafted the phrase into the field of higher education; then, it refers to the internal power system and externalization ability mode of a series of activities such as knowledge production, dissemination, and service in universities [14], or a kind of systematic quality or overall

quality formed through the emergence of the system [15]. The core competence of research universities refers to the capabilities or capability system of a research university formed during a long period of time based on its internal advantages and its access channels to external resources, which enable the schools to effectively integrate various educational resources (manpower, finance, materials, knowledge, and information) and obtain long-term competitive advantages; these capabilities or capability system are generally recognized by the society, they make the schools different from their competitors of the same level [16], they are the cornerstones of their legal existence and sustainable development, and they are the key to achieving breakthroughs in the construction of “double first-class” universities.

Since 2005, as an important base for senior talent cultivation, scientific innovation, social service, and cultural inheritance in China [17], research universities are developing towards the goal of “accelerating the construction of a number of high-level universities, especially a number of world-renowned high-level research universities [18].” After more than 10 years of reform and development, China’s research universities have built their own talent cultivation systems, and they have cultivated a large number of excellent technical talents and high-level outstanding talents, produced a large number of top-level academic research outcomes, conquered many scientific and technological difficulties, carried out multilevel, multiform, multiregion, and multichannel decision-making consulting and scientific and technological services, improved the level of scientific and technological achievement transformation, and fostered new economic growth points for the sustainable development of the economy and the society.

As can be seen from Figure 1, whether it is in the separate rankings QS and THE initiated from 2010 or in USNEWS, the formal rankings of global universities launched since 2014, the number of Chinese mainland universities listed in the top 500 has all increased, and all listed Chinese universities are research universities. In particular, according to the ARWU Top 500 rankings released during 2005–2018, the number of listed research universities in mainland China had increased rapidly at a compound annual growth rate of 15%; the core competence had been greatly improved, and the development potential is great. “According to the resource-based view, for the formation of a company’s sustainable competitive advantages, the complex and vague stock resources that reflect history and culture are more effective than the flow resources” [19]; therefore, it is foreseeable that Chinese research universities will maintain their competitive advantages in the next round of competition among first-class universities in the world. According to the newly released QS2019, THE2019, and USNEWS2019 rankings, the number of Chinese mainland research universities ranked among the “Top 500” reached 22, 14, and 32, respectively, which have maintained a good upward trend compared with last year; Tsinghua University, as the leading research university in China, had entered the World Top 50 in these lists and ranked 17, 22, and 50, respectively, further showing that China has basically built a high-quality

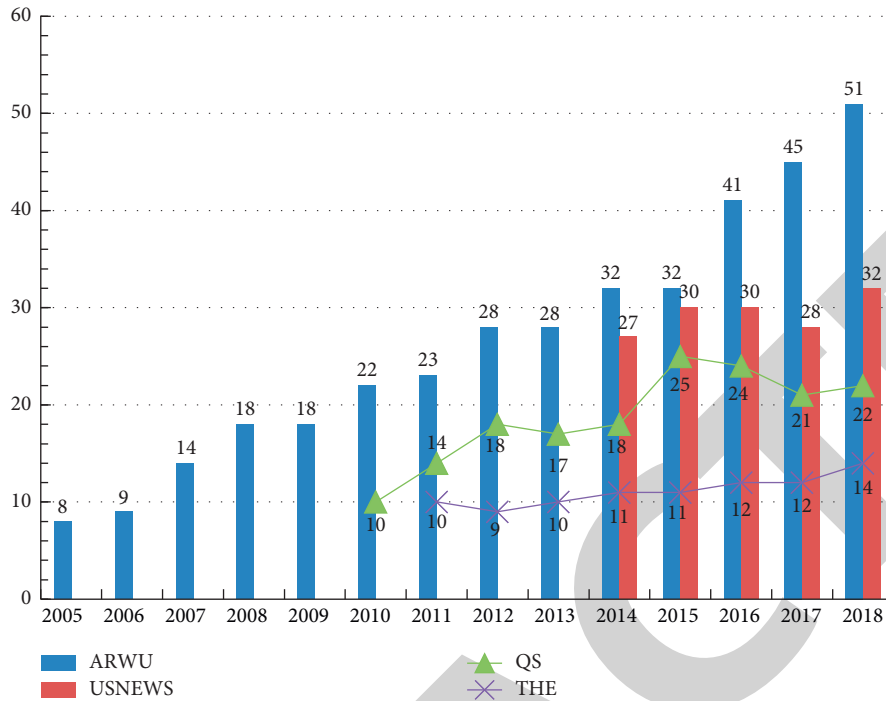


FIGURE 1: Number of Chinese mainland universities listed in the four major rankings.

academic ecological environment that is conducive to the cultivation of the core competence of research universities.

3. Data and Methods

3.1. Data Description. Based on role difference, related studies of foreign scholars mainly focus on the core competence of community colleges [20] or the cultivation of core competence of college students [21, 22], and these studies are mostly qualitative analysis. In recent years, domestic scholars have made some useful explorations on the influencing factors of the core competence of colleges and universities, and they all agree that there are many influencing factors that are closely related to the positioning, level, and type of the universities. In terms of the research on the core competence of research universities, influencing factors such as scientific positioning ability, resource integration ability, innovation ability [23], academic competence, talent competence, scientific research competence [24], professional competence, social service competence, and organizational competence [25] had all been mentioned; however, it still lacks quantitative analysis and mostly are qualitative statements, which cannot effectively reveal the quantitative limits that will cause the qualitative changes.

At the same time, the evaluation indicator systems of world-renowned academic evaluation institutions can reflect the essential characteristics of world-class universities to a certain extent [26], especially the four major rankings focusing on scientific research evaluation: USNEWS, QS, THE, and ARWU, and they directly target at the core competence of first-class research universities and have been regarded as the criteria around the globe. Therefore, based on the important indicators of the four major lists and the feasibility of

data acquisition, from the perspective of the input-output dimensions, this study takes the same-period statistical data of 5 universities including Tsinghua University, Peking University, Fudan University, Nanjing University, and University of Science and Technology of China as samples, the 5 universities are directly subordinate to the Ministry of Education of China, and all were listed in the “World Top 300” of News, QS, THE, and ARWU in 2014–2018; 30 typical indicators that can effectively represent the core competence of research universities had been selected and refined into four categories: input (X_1 – X_4), talent output (X_5 – X_9), academic output (X_{10} – X_{28}), and social service output (X_{29} – X_{30}). Under each category, a few variables were set respectively, as shown in Table 1.

Data sources: official websites of US News, QS, THE, and ARWU; Scientific and Technical Statistics of Higher Education (2014–2018), wherein values with \otimes are estimated values obtained from the average growth rate of the previous four years after significant mutations have been removed.

The data shows that, in the five years since 2014, the growth rates of the 30 representative indicators have mostly doubled, and only a few indicators have declined slightly. The indicator X_{15} representing the proportion of highly-cited papers (top 10%) in 2018 declined to 88% of that in 2014; meanwhile, the indicator X_{11} representing the number of published academic papers increased by 1.41, and the indicator X_{14} representing the number of highly-cited papers (top 10%) increased by 1.19, and this shows that the increment and growth rate of the number of academic papers are much higher those of highly-cited (top 10%) papers. The performances of indicator X_{10} representing the academic reputation and indicator X_{29} representing the social service output employer reputation were both worse than before.

TABLE 1: Description of the influencing indicators of the core competence of Chinese research universities (2014–2018).

Variables	Indicators	Attributes	Ranking source (proportion %)	2014	2018	Amount of change
Y	Core competence of research university		USNEWS, QS, THE, and ARWU	49.65	60.04	1.21
X_1	Teacher-student ratio	Input, objective, and relative	QS (20%) and THE (4.5%)	64.00	68.12	1.06
X_2	Number of teachers with highly-cited research papers	Input, objective, and absolute	ARWU (20%)	10.00	26.00	2.60
X_3	Ratio of international teachers (also called the domestic-international teacher ratio)	Input, objective, and relative	QS (5%)	38.02	61.86	1.63
		Input, objective, and relative	THE (2.5%)	-	-	-
X_4	Proportion of PhD researchers	Input, objective, and relative	THE (6%)	80.55	87.17	1.08
X_5	Teaching reputation	Output, subjective, and absolute	THE (15%)	25.12	35.69	1.42
X_6	Doctorate-bachelor degree ratio	Output, objective, and relative	THE (2.25%)	37.88	43.55	1.15
X_7	Proportion of international students (also called the domestic-international student ratio)	Output, objective, and relative	QS (5%)	27.38	28.88	1.05
		Output, objective, and relative	THE (2.5%)	-	-	-
X_8	Equivalent number of alumni awarded Nobel Prize or Fields Medal	Output, objective, and absolute	ARWU (10%)	2.10	4.32	2.06
X_9	Average teacher income in institution that can provide greater teaching convenience	Output, objective, and relative	THE (2.25%)	3.77	5.35	1.42
X_{10}	Academic reputation	Output, subjective, and absolute	QS (40%), THE (18%), and USNEWS (12.5% each in globe and regions)	87.80	78.00	0.89
X_{11}	Number of published academic papers	Output, objective, and absolute	USNEWS (10%)	10071.00	14214.00 [*]	1.41
X_{12}	Number of papers cited by SCIE and SSCI	Output, objective, and absolute	ARWU (20%)	56.32	65.98	1.17
X_{13}	Equivalent number of papers published by nature or science	Output, objective, and absolute	ARWU (20%)	16.70	22.96	1.37
X_{14}	Number of highly-cited papers (top 10%)	Output, objective, and absolute	USNEWS (12.5%)	7.03	8.36	1.19
X_{15}	Proportion of highly-cited papers (top 10%)	Output, objective, and relative	USNEWS (10%)	0.08	0.07	0.88
X_{16}	Number of highly-cited (first 1%) papers in ESI subjects	Output, objective, and absolute	USNEWS (5%)	291.20	482.60	1.66
X_{17}	Proportion of highly-cited papers (top 1%)	Output, objective, and relative	USNEWS (5%)	3.00	4.03	1.34
X_{18}	Total frequency of cited papers	Output, objective, and relative	USNEWS (7.5%)	328557.60	880354.60	2.68

TABLE 1: Continued.

Variables	Indicators	Attributes	Ranking source (proportion %)	2014	2018	Amount of change
X_{19}	Number of published papers (per teacher)	Output, objective, and relative	THE (6%)	4.02	6.04	1.50
X_{20}	Number of citations of papers published (per teacher)	Output, objective, and relative	QS (20%)	57.10	78.32	1.37
X_{21}	Number of citations of papers published (per paper)	Output, objective, and relative	THE (30%)	64.58	73.84	1.14
X_{22}	Impact index of standardized citation	Output, objective, and relative	USNEWS (10%)	5.62	6.69	1.19
X_{23}	Proportion of international cooperated papers	Output, objective, and relative	USNEWS (5%) and THE (2.5%)	14.15	15.37	1.09
X_{24}	Proportion of international cooperated paper published by the target institution in the international cooperated paper published by the country	Output, objective, and relative	USNEWS (5%)	2.81	3.34	1.19
X_{25}	Number of academic monographs	Output, objective, and absolute	USNEWS (2.5%)	184.40	236.18 [✱]	1.28
X_{26}	Number of conference papers	Output, objective, and absolute	USNEWS (2.5%)	2502.00	4363.21 [✱]	1.74
X_{27}	Research income (per teacher)	Output, objective, and relative	THE (6%)	8.59	13.36	1.55
X_{28}	Average academic performance per teacher	Output, objective, and relative	ARWU (10%)	20.30	23.08	1.14
X_{29}	Employer reputation	Output, objective, and absolute	QS (10%)	84.26	74.44	0.88
X_{30}	Average industry income of teachers (for knowledge transfer)	Output, objective, and relative	THE (2.5%)	74.48	74.30	1.00

On the one hand, this may be caused by the two indicators' characteristics of "extremely important, but cannot be accurately quantified" [27], and it will inevitably result in the "contradiction between the nonquantitative subjective evaluation and the unified objective standards" [28]; on the other hand, this may be related to insufficient first-class scientific research output and the weak international academic influence. In addition, indicators X_1 , X_4 , and X_{23} grew slowly and the increment was small, reflecting that there is still much room for the development of Chinese research universities in terms of faculty scale X_1 (teacher-student ratio), faculty level X_4 (proportion of PhD researchers), and internationalization degree X_{23} (proportion of international cooperated papers); another highly related indicator X_{30} (average industry income of teachers) even showed a rare negative growth, reflecting that the conversion rate of scientific and technological achievements of research universities in China seriously lagged behind the international level, and the ability to realize industrialization and create

market value needs to be improved as well; indicator X_7 (proportion of international students) developed slowly, showing great potential of research universities to open up to the outside world and realize education internationalization. It is not difficult to see that although the core competence indicators of Chinese research universities have grown steadily each year, compared with world-class universities in other countries, there is still an obvious gap, especially in terms of faculty level, for instance, indicator X_8 (equivalent number of alumni awarded Nobel Prize or Fields Medal) accounts for up to 20% in ARWU, but in China, this indicator has been zero all the time, and until now, no breakthrough has been made yet, and this indicator has not been included in the list, which has further confirmed the practical judgement of Mr. Yang Wei, the academician of the Chinese Academy of Sciences, the academician of the World Academy of Sciences, and the president of Zhejiang University, that the biggest gap between Chinese research universities and the world-class universities is teachers [29].

3.2. Weight Determination. The entropy value can measure the degree of disorder and randomness of a system; this value is used to judge the degree of discreteness of indicators, thereby measuring the influence degree of different factors on a comprehensive evaluation [30]. In information theory, entropy is a metric for uncertainty. The greater the amount of information, the less the uncertainty and the smaller the entropy. The inverse is also true. According to the properties of entropy, an index with a high entropy is highly dispersed and has a large impact on the composite evaluation. In the process of multiattribute decision-making, this objective weighting method has strong theoretical support, and it not only can reflect the discriminating ability of indicators through system information but also can reduce the subjective arbitrariness caused by individual differences; therefore, it is of high credibility and accuracy. As far as this study is concerned, 90% of the 30 representative factors are objective indicators (Table 1). The remaining 10 subjective indicators, such as teaching reputation in THE and academic reputation and employer reputation in QS, were obtained through questionnaire surveys on tens of thousands of professional experts and the employment situation of college graduates. Therefore, the entropy value can better reflect the influence direction of the indicators on the target. The specific operations are as follows:

- (1) Information sorting: N indicators from m years of the 5 research universities were selected to construct the original data matrix $X = \{X_{ij} | i = 1, 2, \dots, m; j = 1, 2, \dots, n\}$
- (2) Data processing: to deal with the inconsistent dimensions between indicators and avoid logarithmic meaninglessness when solving the entropy value, $X'_{ij} = \{X_{ij} - \min(X_{1j}, X_{2j}, \dots, X_{mj}) / \max(X_{1j}, X_{2j}, \dots, X_{mj}) - \min(X_{1j}, X_{2j}, \dots, X_{mj}) + 1 | i = 1, 2, \dots, m; j = 1, 2, \dots, n\}$ was taken to standardize the data
- (3) Calculate the specific gravity $P_{ij} = \{X'_{ij} / \sum_{i=1}^m X'_{ij} | i = 1, 2, \dots, m; j = 1, 2, \dots, n\}$
- (4) Calculate the information entropy $E_j = \{-\ln(m)^{-1} \sum_{i=1}^m P_{ij} \ln P_{ij} | i = 1, 2, \dots, m; j = 1, 2, \dots, n\}$
- (5) Calculate the weight $W_j = \{(1 - E_j) / \sum (1 - E_j) | j = 1, 2, \dots, n\}$

3.3. Gray Relation. The gray relation degree determines the degree of relation between factors by finding out the correlation between the factors and judging whether the change trend of each factor is the same, and this method is particularly suitable for the analysis of the dynamic change processes [31]. The method can deeply reflect the closeness of the reference sequence and the comparison sequence with respect to the change rate of the initial point; it can make up for the defects that mathematical analysis methods such as regression analysis, variance analysis, and principal component analysis are linear and unrelated to the sequence; it can also overcome the deficiencies of relying solely on models for quantification and directly find out the primary and secondary important factors in the system development process; moreover, the method has no special requirements

for the sample size and regularity, and situations such as inconsistency between quantitative results and qualitative analysis results will not occur [32]. For this study, the fluctuation of the 30 representative factors has important influence on the core competence of research universities, and the latter also responds accordingly; this two-way interaction is full of uncertainty and randomness; therefore, the gray relation model could be adopted to give explanations, and the specific operations are as follows:

- (1) Select the sequences: assume the reference sequence is $X_0 = \{X_0(i) | i = 1, 2, \dots, m\}$, and the comparison sequence is $X_j = \{X_j(i) | i = 1, 2, \dots, m; j = 1, 2, \dots, n\}$
- (2) Data processing: use the normalized dimensionless method to process $X'_0 = \{(X_0(i)/X_0(l)) | i = 1, 2, \dots, m\}$ and $X'_j = \{(X_j(i)/X_j(l)) | i = 1, 2, \dots, m; j = 1, 2, \dots, n\}$, wherein $X_0(l)$ and $X_j(l)$ are initial values
- (3) Calculate the correlation coefficient, namely, the correlation coefficient between the sequence $X_0(k)$ and sequence $X_j(k)$, and $\xi_j(i) = \frac{\min_j \min_i |x'_0(i) - x'_j(i)|}{\rho \max_j \max_i |x'_0(i) - x'_j(i)|} \wedge \frac{|x'_0(i) - x'_j(i)|}{\rho \max_j \max_i |x'_0(i) - x'_j(i)|}$, wherein the identification coefficient $\rho \in (0, 1)$, and its value generally takes 0.5 [35]
- (4) Calculate the gray relation degree: $\gamma_{0j} = (1/m) \sum_{i=1}^m \xi_j(i)$, $i = 1, 2, \dots, m$ and $j = 1, 2, \dots, n$
- (5) Calculate the comprehensive gray relation degree: according to the weight previously obtained, the comprehensive gray relation degree $\lambda_{0j} = \sum_{j=1}^n w_j \gamma_{0j}$

4. Results and Analysis

4.1. Weight Determination. Judging from the indicator weights estimated by the entropy method (see Table 2), they are mainly distributed within the interval of 0.0259–0.0516, which is relatively balanced, neither too high nor too low. Relatively speaking, indicator X_8 (0.0516) is an important one, indicating the equivalent number of alumni awarded Nobel Prize or Fields Medal is especially important in the core competence system of research universities, and it plays as a role of strategic and basic lever, which is consistent with the conclusion of Professor Miao Qiumin who used the rigid indicator of the number of Nobel Prize winners to examine the four major ranking systems and found out that the ranks of the universities with top ten numbers of Nobel Prize winners are basically consistent with the ranks of these universities in the lists of the ranking systems [33]. In addition, the other four top 5 indicators were average industry income of teachers (for knowledge transfer) X_{30} (0.0459), average academic performance per teacher X_{28} (0.0449), number of teachers with highly-cited research papers X_2 (0.0413), and proportion of highly-cited papers (top 1%) X_{17} (0.0408). The top five indicators account for 22.45% of the total weight of the 30 indicators and contribute greatly to the core competitiveness of research universities. Among these indicators, the one with the lowest weight is a feature indicator of the QS world university rankings, X_{20} , the number

TABLE 2: Weights of indicators for the core competence of Chinese research universities.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
W_j	0.0313	0.0413	0.0312	0.0320	0.0289	0.0278	0.0264	0.0516	0.0289	0.0273
	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
W_j	0.0344	0.0326	0.0395	0.0260	0.0368	0.0304	0.0408	0.0314	0.0306	0.0259
	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{29}	X_{30}
W_j	0.0309	0.0260	0.0323	0.0260	0.0382	0.0390	0.0329	0.0449	0.0286	0.0458

of citations of papers published (per teacher), which does not appear in other ranking systems such as QS Asian University Ranking, QS Latin American University Ranking, QS BRICS University Ranking, and QS Chinese Mainland University Ranking. Admittedly, this indicator is an important measure of the high-level research results of universities, a mirror of the academic attention and recognition of the research results, and a demonstrator of the leading and guidance roles of universities in the relevant disciplines. Since Chinese mainland starts to rank universities by the number of highly-cited (first 1%) papers in ESI subjects, it is expected that the number of citations of papers published (per teacher) will be assigned a greater weight among the indicators of the core competitiveness of research universities.

4.2. Gray Relation Degree. Gray relation measures the correlation and trend between the reference sequence (namely, the core competence of Chinese research universities) that reflects the system behavior characteristics and the comparison sequence (influencing factors) that affects the system behavior. In terms of single indicators (see Table 3), the one with the highest gray relation degree is X_{28} (the average academic performance of teachers), which is as high as 0.97, followed by X_6 (doctorate-bachelor degree ratio), X_{14} (number of highly-cited papers (top 10%)), X_{22} (impact index of standardized citation), and X_{24} (proportion of international cooperated paper published by the target institution in the international cooperated paper published by the country), all of which have a gray relation degree of 0.96; remaining indicators ranked the top five are, respectively, X_{12} (number of papers cited by SCIE and SSCI) with a gray relation degree of 0.95, X_1 (teacher-student ratio) with a gray relation degree of 0.93, and X_{21} (number of citations of papers published (per paper)) with a gray relation degree of 0.92; indicators ranked the sixth include X_4 (proportion of PhD researchers), X_{30} (average industry income of teachers), and X_{13} (equivalent number of papers published by Nature or Science), with a gray relation degree of 0.91; X_{17} (proportion of highly-cited papers (top 1%)) ranked the seventh with a gray relation degree of 0.90. The abovementioned factors are all included in the first group that has the greatest impact on the core competence of Chinese research universities in the past five years (2014–2018). The second group indicators (gray relation degree between 0.89 and 0.88) have large impact on the core competence of Chinese research universities, and these indicators are mainly X_{25} , X_5 , and X_9 ranked the eighth and X_{11} and X_{19} ranked the ninth, respectively, are the number of academic monographs, the teaching reputation, the average teacher income in

institution that can provide greater teaching convenience, the number of published academic papers (include reviews and newsletters), and the number of published papers (per teacher). The third group indicators have a gray relation degree between 0.87 and 0.80, and they have an impact on the core competence of Chinese research universities, including X_{23} , X_{15} , X_{16} , X_{10} , X_{29} , X_{26} , X_{20} , and X_{27} , which are, respectively, the proportion of international cooperated papers, the proportion of highly-cited papers (top 10%), the number of highly-cited (first 1%) papers in ESI subjects, the academic reputation, the employer reputation, the number of conference papers, the number of citations of papers published (per teacher), and the research income (per teacher). The left indicators have lower gray relation degrees; therefore, compared with above groups, the impact is not significant; for instance, the gray relation degrees of X_3 , X_8 , X_2 , X_{18} , and X_7 are all less than 0.80, indicating that the indicators of the ratio of international teachers, the equivalent number of alumni awarded Nobel Prize or Fields Medal, the number of teachers with highly-cited research papers, the total frequency of cited papers, and the proportion of international students are not consistent with the slope of the development curve of the core competence of Chinese research universities. In summary, indicators of a same category may have different or very different gray relation degrees, and this indicates that although the gray relationship method proves the relevant development direction, it should be combined with the actual situation and China’s local scientific research characteristics to re-planning and key direction allocation.

From the factor combinations (see Table 4), we can see that there is $\gamma_{0r} = \gamma_{0s} > \gamma_{0i} > \gamma_{0b}$, indicating that, in 2014–2018, the influencing factors of the core competence of Chinese research universities can be ranked as academic output, social service output, talent output, and input. Both academic output and social service output are influencing factors ranked the first; and, the talent output ranked the second. This fully reflects “a brand-new change in the functional positioning of universities; in recent years, the functions and roles of the universities have undergone fundamental transformation, and the weight of scientific research works has exceeded the weight of teaching works” [34]. To a certain extent, the four authoritative rankings have become a powerful engine for the connotative development of higher education; however, we must also be aware that these rankings focus more on indicators such as academic credibility, research quality, academic research results, and comprehensive scientific research level, and it is difficult to explain the impact on talent cultivation using clear and specific qualitative indicators. At the same time, we should

TABLE 3: Distribution of gray relation degrees of the core competence indicators of Chinese research universities.

Groups	Range	Factors											
The first group	>0.90	X_{28} (0.97)	X_6 (0.96)	X_{14} (0.96)	X_{22} (0.96)	X_{24} (0.96)	X_{12} (0.95)	X_1 (0.93)	X_{21} (0.92)	X_4 (0.91)	X_{30} (0.91)	X_{13} (0.91)	X_{17} (0.90)
The second group	0.89–0.88	X_{25} (0.89)	X_5 (0.89)	X_9 (0.89)	X_{11} (0.88)	X_{19} (0.88)							
The third group	0.87–0.80	X_{23} (0.87)	X_{15} (0.86)	X_{16} (0.84)	X_{10} (0.84)	X_{29} (0.84)	X_{26} (0.83)	X_{20} (0.80)	X_{27} (0.80)				
The fourth group	< 0.80	X_3 (0.76)	X_8 (0.65)	X_2 (0.63)	X_{18} (0.61)	X_7 (0.58)							

TABLE 4: Distribution of the gray relation degrees of the core competence indicators of Chinese research universities.

Input		Talent output		Academic output				Social service output	
γ_{01}	0.93	γ_{05}	0.89	γ_{010}	0.84	γ_{020}	0.80	γ_{029}	0.84
γ_{02}	0.63	γ_{06}	0.96	γ_{011}	0.88	γ_{021}	0.92	γ_{030}	0.91
γ_{03}	0.76	γ_{07}	0.58	γ_{012}	0.95	γ_{022}	0.96		
γ_{04}	0.91	γ_{08}	0.65	γ_{013}	0.91	γ_{023}	0.87		
		γ_{09}	0.89	γ_{014}	0.96	γ_{024}	0.96		
				γ_{015}	0.86	γ_{025}	0.89		
				γ_{016}	0.84	γ_{026}	0.83		
				γ_{017}	0.90	γ_{027}	0.80		
				γ_{018}	0.61	γ_{028}	0.97		
				γ_{019}	0.88				
γ_{0i}	0.81	γ_{0t}	0.79	γ_{0r}	0.87			γ_{0s}	0.87

TABLE 5: Comprehensive gray relation degree shares of the core competence indicators of Chinese research universities.

λ_{0j}	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
	0.0290	0.0259	0.0237	0.0291	0.0259	0.0267	0.0152	0.0333	0.0259	0.0230
	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
0.8485	0.0304	0.0310	0.0359	0.0248	0.0315	0.0256	0.0367	0.0193	0.0269	0.0208
	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{29}	X_{30}
	0.0285	0.0248	0.0281	0.0248	0.0342	0.0324	0.0262	0.0434	0.0240	0.0415

also correctly recognize the importance of the role of talent cultivation in China’s “double first-class” construction, as chairman Xi Jinping said, “Only universities that can cultivate first-class talents can become world-class universities.” Note that the low-ranking inputs are not necessarily unimportant. Their positions are determined by the fact that the four authoritative rankings emphasize outputs over process and inputs. Hence, the ranking of inputs does not lead to the conclusions that “China’s research universities cannot meet the needs of building world first-class universities, due to the low guarantees of higher education resources such as manpower, finance, and materials.”

4.3. *Comprehensive Gray Relation Degree.* After calculation, the comprehensive gray relation degree between the core competence of research universities and the research university core competence system constituted by 30 influencing factors is 0.8485 (see Table 5). It not only shows that the core competence of Chinese research universities has a strong dependence on the system constituted by all these

factors but also verifies the scientificity and rationality of the four authoritative rankings to some extent. Although it cannot cover all the goals of the strategy of “double first-class” construction, it points out a direction for the efforts to enhance the core competence of research universities.

5. Conclusion and Discussion

In recent years, the higher education in China has developed vigorously and achieved achievements that have attracted worldwide attention. The numbers and ranks of Chinese universities in the four major rankings of USNews, QS, THE, and ARWU have been rising continuously, which is a reflection of the driving effect of the strategy of “double first-class” construction. However, as the main force of the “double first-class” construction, in which aspects could the core competence of research universities be reflected? And, where is the direction of development? Based on this, this paper drew on 30 typical indicators in the four major rankings that can effectively represent the internal core competence system of the research universities and selected

the same period statistical data of the five research universities directly subordinate to the Ministry of Education of China; all these five schools were shortlisted in the “World 300” rankings of USNews, QS, THE, and ARWU from 2014 to 2018; the paper adopted empirical quantitative research methods to calculate the gray relation degree between the core competence of Chinese research universities and various factors and found that according to the degree of dependence, they can be ranked as: academic output, social service output, and talent output and input.

As shown in Table 1, with the growing core competitiveness of China’s research universities (49.65 in 2014 to 60.04 in 2018), different degrees of negative growths were observed on X_{15} (0.08 in 2014 to 0.07 in 2018) and X_{10} (87.80 in 2014 to 78.00 in 2018), which represent academic output, as well as X_{29} (84.26 in 2014 to 78.00 in 2018) and X_{30} (74.48 in 2014 to 74.30 in 2018), which represent social service output. The core competence of Chinese research universities and these four indicators showed significant gray relations, which is very consistent with the analysis results of the gray relation combinations of the influencing indicators, and it can be seen that the academic outcome and social service outcome had a promotive effect on the core competence of Chinese research universities. Of course, talent cultivation is the sword of Damocles for the higher education, and it is a red line that cannot be crossed at any time. At the same time, by constructing the comprehensive gray relation, the correlation between the core competence of the research universities and the internal core competence system was estimated, and the results showed that the gray relation between the two was strongly dependent.

The four major rankings have their respective advantages and disadvantages, failing to fully reflect the development status of higher education in a country. However, these four “third-party international university evaluation criteria” are widely recognized by universities and highly objective” [36] and clearly reflect the improvement direction of the core competitiveness of China’s research universities; with the continuous progress and value reorientation of the human society, the functions of universities become increasingly diverse, involving “talent cultivation, knowledge innovation, social services, cultural inheritance, and innovation, as well as international exchange and cooperation” [37].

Similarly, although the ultimate goal of the “double first-class” construction strategy is to enhance the overall level of China’s higher education system, China must learn from Germany’s “Elite University Project” (2005) to break free from the shackles of equalitarianism and invest heavily on the few high-level research universities. The specific measures include stepping up the evaluation and encouragement of the key links of these universities, such as research level, social service reputation, employer reputation, and talent cultivation quality. The focal point should be diversifying the homogenous development path, overcoming the constraints of solidified identities, weak competitions, and functional overlaps, and strengthening the spillover effect of the “double first-class” construction on higher education development.

The research is limited in the following aspect: many less well-known research universities have not timely disclosed their firsthand data. Due to the poor availability of data, this paper does not extend the research scope to these less well-known universities. In future, the samples will be further expanded to widen the scope of discussion.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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