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Performance Evaluation of Scientific Research in China's First-class Universities from the Perspective of Multi-agent

Based on Malmquist index, SE-DEA and SFA Respectively*

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***Abstract*—The research performance of 42 universities is measured based on the perspectives of society, universities and the country. From the perspective of society, the productivity of scientific research in first-class universities is declining, mainly due to the decline of technology; the universities with rising productivity and decline can be attributed to horizontal catch-up drive and vertical regression. From the perspective of colleges and universities, the overall efficiency of the first-class universities is effective; the comprehensive and effective colleges and universities can be called the insufficient input-driven and the insufficient output constraints. From the perspective of the state, the technical efficiency of first-class universities is low and mainly caused by management factors; the universities with effective technical efficiency are driven by low management and the ineffective universities are comprehensively restricted by technical regression and management. It is suggested that in terms of project cooperation and resource allocation, society and the state should give priority to universities with high productivity, high efficiency and effective management; low-efficiency universities should pay attention to technological improvement, strengthen output orientation and improve management capabilities.**

Keywords—first-class university; research performance; ultra-efficient data envelopment analysis; Malmquist index; stochastic frontier analysis

I. INTRODUCTION

"The Overall Plan for Coordinating the Promotion of World-class Universities and First-class Disciplines" pointed out that China's previous university construction projects have problems such as identity solidification, lack of competition, and repeated crossovers, and proposed to "encourage differentiated development", "highlight performance-oriented" and "remote adjustment support" and other reform-oriented reform measures; "The Implementation Measures of Coordinating the Promotion of World-class Universities and First-class Disciplines (Provisional)" stipulates that in the middle and final period of the construction of universities, self-evaluation should be carried out; the "double-first-class" construction expert committee should make the performance evaluation of colleges and universities; and the state dynamically adjusts the scope of construction according to the evaluation results. Nowadays, the mid-term evaluation work is approaching, and how the various stakeholders conduct self-evaluation, evaluation and rational allocation of resources, the key is to formulate performance evaluation methods and propose evaluation criteria. Performance is a relative concept. A natural measure of performance refers to the ratio of input to output, that is, productivity and efficiency (also called relative productivity, the ratio of individual productivity to the maximum productivity in a group), [1][1-2], [2][15] Therefore, in view of the above problems, this paper conducts an empirical analysis of the productivity and efficiency of first-class universities, with a view to making suggestions for promoting the connotative development of colleges and universities and promoting the construction of world-class universities with Chinese characteristics.

II. LITERATURE REVIEW

The evaluation methods of university efficiency are diverse and mainly quantitative methods, such as regression analysis method, data envelopment analysis method, and stochastic frontier method. For example, Ding Lan used the regression method to analyze the production efficiency of 68

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colleges and universities, and found that the capital investment and the number of young teachers are the main factors affecting the production efficiency of colleges and universities [3]; Hu Yongmei and Andrew used the Malmquist index to analyze the productivity changes of colleges and universities, pointing out Technological progress is an important factor in improving productivity [4], [5], [6]; Horne Jocelyn and Hu Baiding used DEA and SFA to analyze the cost efficiency and technical efficiency of universities in different regions; [7], [8], [9] some scholars used factor analysis and synthesis. Other methods such as the evaluation method have carried out research on the efficiency of famous universities in China. [10], [11]

The university efficiency evaluation index system is scientific in its construction. The indicators include many aspects such as personnel training, scientific research and social services. Academic resources, tutors, and education funds are generally used as input indicators, while scientific research achievements, and personnel training being used as output indicators. For example, Xie Youcai, Garcia-Aracil and Adela used the number of tutors and research funds as input indicators, the number of graduate students and scientific research results as output indicators; [12], [13], [14] Xu Juan and others took teaching and research personnel, science and technology funds as input indicators and transformation of subjects, monographs and results as output indicators. [15], [10] Johnes et al. added material resources such as teaching and research instruments and books to the input indicators, and added discipline construction and patent grants to the output indicators. [16], [17], [18], [19], [12]

It can be seen that the research on the efficiency evaluation of colleges and universities at home and abroad has been relatively mature, but in general, the following problems still need to be solved: (1) The research object is clear, but the subjective perspective is single. In the study of university efficiency evaluation, scholars have uncontroversially regarded universities as decision-making units, but a large number of studies have not mentioned or distinguished evaluation subjects, neglecting the appeals and core concerns of different subjects and different positions. (2) Research methods are normative, but they are lack of contrast. In many studies, index method, DEA and other methods are used properly. The efficiency analysis of colleges and universities is thorough and appropriate policy recommendations are put forward. However, there are few methods for comparative research, which is aware of the limitations of this method, but no other methods are used to make up for it. (3) The evaluation indicators are comprehensive, but the definition of input and output is arbitrary. Most of the papers have adopted the principles of completeness and conciseness in their index system, but they are more casual in the input and output attribution of indicators, lacking profound and dialectical thinking. This study intends to break through the above three issues as key tasks.

III. THEORIES AND METHODS

A. *Malmquist Index Method*

In 1994, Fare R et al. gave the calculation formula of Total Factor Productivity Changer (TFPC) Malmquist index from t period to t+1 period. Under the assumption of constant return to scale [20][1] 70:

$$TFPC = M_0^{t+1,t}{}_i(Y_{t+1},X_{t+1},Y_t,X_t) = \frac{d_0^{t+1}(Y_{t+1},X_{t+1})}{d_0^t(Y_t,X_t)}\left[\frac{d_0^t(Y_{t+1},X_{t+1})}{d_0^{t+1}(Y_{t+1},X_{t+1})}\cdot\frac{d_0^t(Y_t,X_t)}{d_0^{t+1}(Y_t,X_t)}\right]^{\frac{1}{2}},$$

wherein $d_0^t(Y_t,X_t)$ represents a distance function of a given input X output as Y in the t period, and $\frac{d_0^{t+1}(Y_{t+1},X_{t+1})}{d_0^t(Y_t,X_t)}$ represents a Technical Efficiency Change (TEC) of the decision unit in two periods t and t+1, That is, the convergence degree of each decision unit to the forward production function can be called the horizontal catch-up effect. $\left[\frac{d_0^t(Y_{t+1},X_{t+1})}{d_0^{t+1}(Y_{t+1},X_{t+1})}\cdot\frac{d_0^t(Y_t,X_t)}{d_0^{t+1}(Y_t,X_t)}\right]^{\frac{1}{2}}$ is Technical Change (TC), which represents the movement of the frontier production function in two periods, indicating technological progress or regression, that is, the vertical growth effect. When the scale is variable, the Technical Efficiency Change (TEC) can be further decomposed into Pure Technical Efficiency Change (PTEC) and Scale Efficiency Change (SC). PTEC is the catch-up effect of eliminating the scale effect. Thus, the Malmquist productivity change index can be expressed as [5], [1]79:

Malmquist Index (TFPC) = Pure Technical Efficiency Change (PTEC) * Scale Efficiency Change (SC) * Technology Change (TC)

When the index is greater than, equal to and less than 1, they respectively represent increase, constant and decline in productivity. When PTEC, SC and TC are greater than, equal to and less than 1, they respectively represent the increase, constant and decline of the horizontal catch-up effect, the scale optimization effect and the vertical growth effect. [5], [1]74-81

B. *Super Efficiency Data Envelopment Analysis (SE-DEA)*

Data Envelopment Analysis (DEA) is a non-parametric analysis method based on relative efficiency proposed by American scholars Charnes, Cooper and Rhodes in 1978 to evaluate the same Decision-Making Unit (DMU) with multiple inputs and multiple outputs. The relative validity of their first model is called the CCR model (assuming scale returns are constant), and future papers consider different assumptions such as Fare, Gross-kopf, and Logan, and Banker, Charnes, and Cooper, respectively proposed the VRS model in 1983 and 1984, the SBM model proposed by Tone Kaoru in 2001, and so on. [21][13][22]151 These models have certain shortcomings, that is, they can only make "effective" or "invalid" points for DMU, and can't further compare the efficiency of "effective" DMU, which

Andersen and Petersen proposed a method for further analyzing the effective degree of effective DMU is called "Super-Efficiency Model". The core of the method is to remove the evaluated DMU from the reference set, that is, the efficiency of the evaluated DMU is based on other DMUs. The frontier of the composition is calculated, the effective value of the effective DMU is generally greater than 1, and then differentiated. The output-oriented CRS super-efficiency model can be expressed as follows [23]:

$$\max \varphi$$

$$s.t. \sum_{\substack{j=1 \\ j\neq k}}^{n} \lambda_j x_{ij} \leq x_{ik}, \quad \sum_{\substack{j=1 \\ j\neq k}}^{n} \lambda_j x_{rj} \geq \varphi y_{rk}, \quad \sum_{\substack{j=1 \\ j\neq k}}^{n} \lambda_j = 1, \quad \lambda \geq 0$$

i=1,2,...,m;r=1,2,...,q;j=1,2,...,n ($j \neq k$), wherein x_{ik} and y_{rk} respectively represent the ith of the kth DMU Input and rth output, λ represents the linear combination coefficient of DMU, and φ is the optimal solution of the model. In addition, the technical efficiency value (integrated technical efficiency) obtained in CRS DEA can be decomposed into Scale Efficiency (SE) and Pure Technology Efficiency (TEVRS). The relationship between the three is: $TE_{CRS} = TE_{VRS} \times SE$, the nature of scale efficiency can be compared by comparing the efficiency of NIRS technology with whether the efficiency of the VRS technology is equal or not is determined. If the two are equal, the DMU has an incremental scale profit, and if there is a difference, there is a diminishing scale profit. [1]173-174

3. Stochastic Frontier Analysis Based on Cobb-Douglas Production Function

In 1992, Battese and Coelli proposed a stochastic frontier production function model for panel data. The model assumes that the inefficiency term obeys the truncated normal distribution. The most commonly used functional forms of the stochastic frontier are Cobb-Douglas production function and Translog production function. In view of the fact that the latter is prone to multi-collinearity problems in the case of multi-factor input, the function form of this paper is selected as follows [24], [25], [26], [27], [28] 16-17:

$$\ln y_{it} = \beta_0 + \beta_x \ln x_{it} + \beta_T t + (v_{it} - u_{it}),$$

$$u_{it} = u_i \exp[-\eta(t - T)], \ i=1, 2, \dots, N; \ t=1, 2, \dots, T$$

In this expression, y_{it} and x_{it} are the output and input of the ith evaluated unit in the tth period; β is the unknown parameter vector. v_{it} is random noise, which indicates the deviation caused by irresistible factors such as statistical measurement error, assuming $v_{it} \sim N(0, \sigma_v^2)$; u_i is a non-negative random variable, which is used to measure the technical inefficiency caused by human factors such as poor management and running, and assumes $u_i \sim iiN^+(\mu, \sigma_u^2)$ is not related to v_i, and η is the parameter to be evaluated considering the time-varying. For the calculation of the maximum likelihood estimator, Battese and Corra replace $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$ with σ_v^2 and σ_u^2. The range of γ is [0, 1]. In addition, Timthy and Coelli gave a production-oriented technical efficiency formula [28] 4-6: $TE_i = \frac{y_i}{\exp(x_i'\beta + v_i)} = \frac{\exp(x_i'\beta + v_i - u_i)}{\exp(x_i'\beta + v_i)} = \exp(-u_i)$.

IV. Indicators and Framework

Through the analysis of the above three methods, the Malmquist index method is mainly used to study the productivity changes of different evaluated units in multiple periods, focusing on its own vertical comparison, and decomposing the horizontal catch-up effect and scale optimization effect that affect the productivity change, the vertical growth effect and other factors; Super-Efficiency DEA applies to the horizontal comparison between multiple evaluated units to reflect the relative effectiveness of each other, and gives the redundancy or deficiency of each input and output; SFA has statistics characteristics, and the decomposition of influencing factors into management factors that cause technical inefficiencies and random factors that are not controlled by themselves.

For social subjects, it is believed that they pay more attention to the long-term performance of top universities, that is, the productivity changes of colleges and universities for many years, which are the universities with rising productivity, and which are the declines. In addition, the rise is due to the obvious horizontal catch-up effect, and the more excellent scale effect, or the greater vertical growth effect? For the universities themselves, since the construction of 42 first-class universities has only been for two years, the middle period of assessment is coming, and the colleges and universities are paying more attention to the construction of the past two years, that is, relative to the efficiency of other universities and the direct causes of the high and low levels. Is it redundant or under-produced, and in what areas is it insufficient or redundant? For the state or the government, it is more important to determine the root cause of the efficiency of the universities, which is caused by the management factors of the university itself or by its uncontrollable factors, and the extent to which the management factors cause the inefficiencies of the universities.

For the input and output of the unit being evaluated, the understanding is that the smaller the input, the better, and the larger the output, the better. [29] 2 According to the applicability of the Malmquist index, Super-Efficiency DEA and SFA methods and the concerns of different subjects, the quantitative relationship between decision-making units and evaluation indicators ($n \geq \max\{m * q, \ 3 * (m + q)\}$, n, m and q respectively represent the decision-making unit, the number of input and output indicators), [30] 237-250 [22] 27 and the above scholars' specific settings for input and output indicators, this paper presents a comprehensive analysis

framework for the productivity and efficiency of 42 first-class universities (see "Table I"). The data comes from the Compilation of Science and Technology Statistics of Colleges and Universities, the Social Science Statistics Summary, the National Graduate Student Enrollment Plan and the official website of 42 universities.

TABLE I. ANALYSIS FRAMEWORK OF RESEARCH PRODUCTIVITY AND EFFICIENCY IN CHINA'S FIRST-CLASS UNIVERSITIES

Subject perspective	comment content	Input indicator	Output indicator	type of data	Evaluation method	Measuring tools
society	Science and technology activities	Total scientific and technological funds, teaching and research personnel, and graduate enrollment	Number of topics, number of identification results, actual income of technology transfer in the current year, national award	Panel data (2010-2017)	Malmquist index method	DEAP 2.1
University	Science and technology activities and development of humanities and social sciences	The amount of internal expenditure, teaching and research personnel, and graduate students in the school	Number of topics, monographs, academic papers, appraisal results or number of research and consulting reports adopted by relevant departments, number of national and ministerial awards, number of A+ subjects	Cross-section data (2017)	Super-Efficiency DEA	MYDEA and DEA-SOLVER Pro5
Country	Humanities and Social Sciences Development	Research and development funding, annual income, total R&D staff, graduate enrollment	Number of Questions and Number of Research and Consultation Reports Adopted by Relevant Authorities	Panel data (2010-2017)	SFA	FRONT4.1

[a.] Note: Due to the lack of postgraduate enrollment data for each of the 42 universities in each year, the number of postgraduate enrollments in the input indicators is the total number of graduate enrollments for the university.

V. THE RESULTS OF EMPIRICAL ANALYSIS

A. Social Subject

From the perspective of social subjects, the content of scientific and technological activities is used as the evaluation content. According to statistics, the average annual investment in science and technology funds, teaching and research personnel and postgraduate enrollment of 41 leading universities in China (National University of Defense Technology) is 55,184,255 thousand yuan. 188,871, 175,202, the number of topics, the number of identification results, the actual income of the year of technology transfer and the national level of the annual output were respectively 136,066, 1,072, 1,130,889 thousand yuan, and 158. According to the analysis of Malmquist index, the total factor productivity change of scientific research in China's first-class universities (industrial efficiency can be regarded as the average of the efficiency of all evaluated units in the industry) [1] 255 is 0.976, among which technical efficiency changes, technological changes, pure technology The change in efficiency and scale efficiency were 1.014, 0.963, 1.006 and 1.008, respectively.

At the university level, there are 13 colleges with a rise in total factor productivity from 2011 to 2017 (31.71%). The three universities with the largest increase in TFP are Renmin University of China, Jilin University, and Minzu University of China, and their TFP changes. The values are 1.251, 1.118 and 1.067 respectively; 20 universities with a rise in technical efficiency (accounting for 48.78%), and the three universities with the highest rise (TEC change value) are Renmin University of China (1.260) and Minzu University of China (1.095), and Xiamen University (1.086); there are 8 colleges with rising technology, the top three are Jilin University (1.118), Northwestern Polytechnical University (1.046), Beihang University (1.039); There are 18 changes in pure technical efficiency, including Xiamen University (1.079), Harbin Institute of Technology (1.057), Beijing Institute of Technology (1.055) and other universities; the scale efficiency changes include 17 universities, with Renmin University of China (1.260), Minzu University of China (1.095), Northwest A&F University (1.024), etc., and the breakdown of total factor productivity of other universities and their decomposition are shown in “Table II”.

B. University Subject

From the perspective of the main body of the university, the evaluation contents include the status of scientific and technological activities and the development of humanities and social sciences. According to statistics, the total input values of the teaching and research personnel, the number of graduate students and the internal expenditure of the 41 first-class universities in 2017 are respectively 234,433, 700,117, 60,378,780 thousand, the number of topics, monographs, academic papers, appraisal results, or the number of research and consulting reports adopted by relevant departments, national and ministerial awards, and A+ subject numbers were respectively 233,685, 6,305, 322,133, 5,415, 188, and 141. According to the ultra-efficiency analysis, the comprehensive efficiency, pure technical efficiency and scale efficiency of the research of 41 first-class universities are respectively 1.438, 1.556 and 0.924. The nature of scale efficiency is the diminishing returns on scale.

TABLE II. PRODUCTIVITY AND EFFICIENCY VALUES OF 42 FIRST-CLASS UNIVERSITIES BASED ON MALMQUIST INDEX, SE-DEA AND SFA RESPECTIVELY

DMU	Malmquist index				SE-DEA				SFA	
	TC	*PECH*	*SC*	*TFPC*	*TEVRS*	*TECRS*	*SE*	*RTS*	*TE*	*ui*
1	0.933	0.988	1.010	0.931	1.202	1.564	0.769	DRS	0.326	1.122
2	0.993	1.000	1.260	1.251	2.994	3.081	0.972	DRS	0.941	0.061
3	0.961	1.000	1.000	0.961	1.156	2.450	0.472	DRS	0.422	0.863
4	1.039	1.000	1.000	1.039	1.162	1.162	1.000	CRS	0.211	1.557
5	0.996	1.055	1.009	1.061	0.947	0.989	0.957	IRS	0.087	2.447
6	0.982	1.000	1.000	0.982	1.731	1.808	0.958	IRS	0.376	0.977
7	0.948	1.000	1.000	0.948	1.025	1.047	0.979	DRS	0.796	0.228
8	0.975	1.000	1.095	1.067	17.777	18.806	0.945	IRS	0.438	0.825
9	0.937	1.042	1.000	0.977	0.935	0.960	0.974	IRS	0.687	0.376
10	1.017	1.029	0.990	1.036	1.022	1.048	0.976	DRS	0.166	1.795
11	0.919	1.009	0.995	0.923	0.810	0.810	1.000	CRS	0.359	1.024
12	1.118	1.000	1.000	1.118	0.955	0.997	0.958	DRS	0.549	0.599
13	0.957	1.057	1.023	1.035	1.140	1.196	0.954	DRS	0.132	2.023
14	0.986	0.994	0.993	0.974	0.991	1.068	0.927	DRS	0.722	0.326
15	0.990	0.961	0.986	0.937	0.563	0.563	1.000	CRS	0.429	0.847
16	1.014	1.021	0.974	1.008	1.336	1.351	0.989	DRS	0.528	0.638
17	0.970	1.008	1.008	0.986	0.810	0.824	0.983	DRS	0.829	0.188
18	1.018	1.036	1.001	1.056	0.871	0.929	0.938	DRS	0.438	0.825
19	0.953	1.047	0.998	0.996	0.664	0.669	0.992	DRS	0.290	1.238
20	0.980	0.991	0.976	0.948	0.787	1.061	0.741	DRS	0.934	0.068
21	1.022	0.999	0.984	1.004	0.796	0.796	1.000	CRS	0.103	2.274
22	0.914	1.079	1.006	0.992	0.791	1.049	0.754	DRS	0.872	0.136
23	0.904	0.990	0.995	0.891	0.778	0.778	1.000	CRS	0.676	0.391
24	0.919	0.981	1.001	0.903	0.808	0.844	0.957	IRS	0.573	0.556
25	0.895	1.027	1.018	0.936	0.993	1.290	0.770	DRS	0.715	0.335
26	0.939	0.954	1.016	0.910	0.739	0.747	0.990	DRS	0.370	0.995
27	0.943	1.044	0.989	0.974	0.952	1.121	0.849	DRS	0.388	0.947
28	0.937	1.022	1.006	0.964	1.350	1.552	0.870	DRS	0.656	0.422
29	0.938	1.000	0.997	0.935	3.689	3.689	1.000	CRS	0.907	0.097
30	0.983	1.012	1.015	1.010	1.181	1.242	0.951	DRS	0.746	0.293
31	0.908	1.001	1.005	0.913	0.885	0.957	0.925	DRS	0.386	0.952
32	1.020	0.941	1.000	0.960	0.675	0.682	0.989	IRS	0.182	1.702
33	0.953	0.998	1.000	0.951	0.773	0.778	0.993	DRS	0.473	0.748
34	1.046	1.015	0.993	1.054	0.833	0.833	1.000	CRS	0.133	2.018
35	0.906	1.000	1.000	0.906	0.798	0.798	1.000	CRS	0.308	1.177
36	-	-	-	-	-	-	-	-	-	-
37	0.932	0.975	1.002	0.910	0.589	0.589	1.000	CRS	0.319	1.143
38	0.931	0.978	0.991	0.902	0.632	0.743	0.850	DRS	0.565	0.571
39	0.976	1.012	0.991	0.979	0.588	0.588	1.000	CRS	0.526	0.642
40	0.900	0.951	0.997	0.854	0.688	0.704	0.976	DRS	0.589	0.530
41	0.944	1.042	1.024	1.008	0.796	0.818	0.974	IRS	0.233	1.457
42	0.930	1.000	1.016	0.945	0.745	0.810	0.920	IRS	0.394	0.932

[a.] Note: DMU is listed as 42 colleges and universities, the serial number is the order of the top universities listed by the State Council; "-" indicates the lack of data.

The IRS, CRS and DRS in the RTS column respectively indicate that the scale is increasing, the scale is constant, and the scale is decreasing.

Overall analysis of input slack and output slack: (1) In terms of input, input slack includes input redundancy (positive value) and insufficient input (negative value), and the input redundancy of teaching and research personnel is 2,915 (improved ratio is 1.24%), the number of postgraduate students was -76421 (-10.92%), and the internal expenditure was 953,001 thousand yuan (1.58%); (2) In items of output, output slack including insufficient output (positive value) and output redundancy (negative value), the number of under-resources in the project is 119,316 (the improvement ratio is 51.06%), and the number of monographs, academic

papers, appraisal results, national awards and A+ subjects are respectively 6,893 (109.33%) and 70,197 (21.79%), 2229 (41.16%), 119 (63.28%) and 138 (98.16%).

At the university level, there are 13 comprehensive and efficient universities (accounting for 31.71%), and the three universities with the highest super-efficiency value are the Minzu University of China, South China University of Technology, and Renmin University of China. There are 18 colleges and universities (43.90%) with effective technical efficiency. The effective scale includes 10 universities including South China University of Technology, Beihang University and Northwestern Polytechnical University, etc. The comprehensive efficiency, pure technical efficiency, scale efficiency and scale nature of other universities can be seen in "Table II". The number of colleges with slack in input and slack in output: (1) In terms of input, there are fewer redundant universities in teaching, researcher, postgraduate and internal expenditures, and the numbers are 10, 7, and 10 respectively. (2)In terms of output, there are a large number of six indicators in the number of topics, monographs and academic papers, and the number of universities is very high, which is more than 30.

C. National Subject

From the perspective of the national subject, the content of the evaluation is the development of humanities and social sciences. According to the above analysis framework, y, K, L, and N are used to express the output of each production unit, the income of research and development funds, the number of R&D personnel, graduate enrollment, and variables like these, plus time variable t, a total of four explanatory variables. After hypothesis testing, it can be drawn a conclusion: For the efficiency of the study of humanities and social science activities of 41 leading universities since 2010, the stochastic frontier model has applicability (inefficiency term exists and compound error is mainly caused by inefficiency term). There is a technical change in the stochastic frontier model (the production function should be in the form of Cobb-Douglas containing time variables), and the model technology changes to Hicks Neutral (technical changes have no relation with R&D expenditure, number of researchers, and the input factors such as the number of graduate students enrolled), and the technical efficiency is time-varying. The results of the four-step hypothesis verification and the final estimation results of the model are shown respectively in "Tables III" and "Table IV".

TABLE III. SUMMARY OF HYPOTHESIS TEST RESULTS

Test	Hypothesis	LLF	LR	Degree of freedom k	$\chi^2_{1-0.05}(k)$	Conclusion
Step 1	H_0: $\gamma=0$	-251.96	387.55	3	7.05	Reject
	H_1: $\gamma\neq0$	-58.18				
Step 2	H_0: $\beta_t=0$	-84.39	52.41	3	7.05	Reject
	H_1: $\beta_t\neq0$	-58.18				
Step 3	H_0: $\beta_{TK}=\beta_{TL}=\beta_{TN}=0$					Accept
	H_1: $\beta_{TK}\neq0$、$\beta_{TL}\neq0$ 或 $\beta_{TN}\neq0$					
Step 4	H_0: $\eta=0$	-76.46	36.56	2	5.14	Reject
	H_1: $\eta\neq0$	-58.18				

As a result, the technical efficiency and technical inefficiency of the research results of 41 first-class universities are 0.482 and 0.729 respectively. It can be seen that in the development of humanities and social sciences, the research technology of China's first-class universities is less efficient, and the degree of technical inefficiency is higher, but in view of year after year, the two show an increasing (annual average growth rate of 4.01%) and a decreasing trend (-4.11%).

At the university level, there are 12 colleges with relatively efficient technical efficiency (average technical efficiency greater than 0.6). The first three are Renmin University of China (0.941), Zhejiang University (0.934), South China University of Technology (0.907), Xiamen University (0.872), East China Normal University (0.829), Beijing Normal University (0.796), Sichuan University (0.746), Fudan University (0.722), Wuhan University (0.715), Nankai University (0.687), Shandong University (0.676), and Sun Yat-sen University (0.656). The technical efficiency and technical inefficiency of other universities are shown in “Table II”.

TABLE IV. FINAL ESTIMATION RESULTS OF THE MODEL

the final mle estimates are:			
	coefficient	***standard-error***	***t-ratio***
beta 0	0.18794968E+00	0.16319653E+01	0.11516769E+00
beta 1	0.18454001E+00	0.39781965E-01	0.46387857E+01
beta 2	0.25682671E+00	0.56539788E-01	0.45424067E+01
beta 3	0.47724751E+00	0.16385961E+00	0.29125391E+01
beta 4	-0.32309803E-01	0.17628446E-01	-0.18328220E+01
sigma-squared	0.59283642E+00	0.31894636E+00	0.18587339E+01
gamma	0.91417563E+00	0.47416107E-01	0.19279854E+02
mu	0.32952219E+00	0.43000139E+00	0.76632820E+00
eta	0.59440598E-01	0.12748255E-01	0.46626456E+01

VI. CONCLUSION AND SUGGESTIONS

A. Conclusion

From the perspective of social subjects, the scientific and technological activities of 41 universities are in a state of decline in productivity. The biggest reason for the decline is the decline in technology, that is, the decline in vertical growth. Universities with increased productivity and decline in productivity and attribution: (1) Among the 13 universities with rising productivity (62%), most of them show an increase in horizontal catch-up effect, while others show an increase in vertical growth effect (54%) or scale optimization effect (54%). There are five universities (54%) with increase in horizontal catch-up effect and scale optimization effects: Beijing Institute of Technology, Nanjing University, Harbin Institute of Technology, Sichuan University, and Northwest A&F University. The horizontal catch-up effect, the vertical growth effect and the scale optimization effect are all rising in Nanjing University. (2) Among the universities (28) with productivity declines, 27 have a vertical growth effect decline, some universities have a horizontal catch-up effect decline (43%) or scale optimization effect decline (39%). There are 6 horizontal catch-up effects, vertical growth effects and scale optimization effects: Fudan University, Zhejiang University, Tongji University, Zhengzhou University, Shandong University and Yunnan University. It can be seen that in terms of scientific and technological activities, the increase in scientific research productivity of first-class universities is driven by the increase of vertical growth effect and scale optimization effect, but the main reason is that the horizontal catch-up effect is rising, that is, the productivity increase can be attributed to the horizontal catch-up drive type; part of the reason for the decline in productivity is the decline in horizontal catch-up effect or scale-optimization effect, but the biggest reason is the decline in vertical growth effect, that is, the decline in productivity is the vertical regression.

From the perspective of the university as subject, the scientific research of the first-class universities is in a state of comprehensive effectiveness and diminishing returns to scale. Compared with the fully effective frontier, the main shortcomings are the monographs, the national awards and the A+ disciplines. Comprehensive efficiency and ineffective colleges and universities and attributions: (1) Among the universities with comprehensive efficiency (13), there are respectively 10, 10, and 6 colleges and universities with insufficient investment in teaching and research personnel, postgraduate students, and internal expenditures in the year., which are under-invested in three aspects are Renmin University of China, China Agricultural University, Minzu University for China, Shanghai Jiao Tong University, South China University of Technology and Sichuan University; Universities with output redundancy in terms of output are only Tsinghua University (with 9% redundancy, identification results, 13% for national and A+ disciplines) and Peking University (17% for academic papers and A+ subjects). (2) Among the universities (28) with inefficient comprehensive efficiency, there are respectively 8, 5, and 6 colleges and universities with redundant input in teaching and research personnel, postgraduate students, and internal expenditures in the current year; For the six output indicators, 28 colleges and universities showed insufficient output. It can be seen that in the overall aspect of the development of science and technology activities and humanities and social sciences, the universities with comprehensive and effective efficiency are mainly because their output is limited and the input is small, that is, the comprehensive efficiency is effectively driven by insufficient input; There are input redundancy and insufficient output, but most colleges are mainly caused by insufficient input and insufficient output, that is, the comprehensive efficiency is invalid, which can be called the output deficiency constraint type.

From the perspective of the national subject, the technical efficiency of the development of humanities and social sciences in China's first-class universities is low, and it is mainly caused by technical inefficiencies which are caused by human factors such as running and management, rather than random factors such as measurement errors or other statistical noise. In addition, the greater correlation with output is the number of postgraduate enrollments (correlation coefficient is 47.72%). The related impacts of research and

development funds and the number of R&D personnel on output are small. At the same time, technological changes are characterized by technological regression. Moreover, the impact of technological regression on output contribution is greater (influence is -44.63%). Universities with relatively effective and ineffective technology and attribution: (1) For colleges and universities with relatively effective technical efficiency (12), the degree of impact of technological regression and management inefficiency on technological efficiency changes is -69.73% and -76.97%, respectively. It can be seen that both have great influence on technical efficiency; (2) For colleges and universities whose technical efficiency is relatively ineffective, the degree of impact of technological regression and management inefficiency on technological efficiency changes are -32.10% and -39.55%, respectively, both of which have certain effects on technical efficiency. On the whole, in terms of the development of humanities and social sciences, colleges with effective technical efficiency can be attributed to low-management-invalid driving, and universities with ineffective technical efficiency can be called comprehensive control of technical regression and management ineffectiveness.

B. Suggestions

Through the above analysis, the suggestions are as follows: In terms of social entities, priority is given to colleges with faster productivity, higher comprehensive efficiency, and lower technical inefficiency in capital investment or project entrustment; for inefficient universities, it is recommended to pay attention to technological improvement. (such as prioritizing the construction of laboratories, engineering centers and other platforms), strengthening output orientation (increasing incentives for those who have technology transfer or appraisal results) and improving management and management capabilities to reduce the degree of technical inefficiency; It is suggested that the relevant national authorities should substantially increase the proportion of resources invested by under-investment-driven universities (such as government funds and graduate enrollment), and steadily increase the resources of universities such as horizontal chasing-driven and low-management-inefficient drivers, and appropriately reduce vertical regression resources such as restrictive, under-constrained, technologically backward, and ineffective management constraints.

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