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Evaluation of Scientific Research in Universities Based on the Idea of Education for Sustainable Development

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Abstract: Our research aims to establish an evaluation framework and evaluate the sustainability of scientific research in universities. Based on the concept of Education for Sustainable Development and the function of scientific research activities, an evaluation framework was constructed including three dimensions: the sustainable trend of scientific research activity, research performance related to the topic of sustainable development, and sustainability of scientific research contributions. Descriptive analysis, Data Envelopment Analysis, and a Statistical Index Method were used to calculate the sustainability of scientific research of world-class universities in China. Results show that China's world-class universities published more articles related to sustainable development than the best-performing universities in the UK and USA. They make sustainable contributions to society through cultivating Ph.D. graduates, publishing research papers, and transforming science and technology. However, the sustainable trend of the scientific research of universities is still to be improved. The result of resource efficiency is relatively low, and attention should be paid to the waste of human and financial resources. In addition, universities should improve their ability to withstand external risks to minimize the influence of external public emergencies such as COVID-19.

Keywords: sustainable development; sustainability; education for sustainable development; scientific research evaluation

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1. Introduction

Countries around the world have attached great importance to sustainable development since the publication of the Brundtland Report. In the modern world, education is an important tool for achieving human sustainable development, and universities have been supplying several types of resources and providing solutions for the sustainable development of society [1,2]. Scientific research is one of the core functions of modern universities and plays an important role in the process by constantly cultivating outstanding graduates, producing useful knowledge, and developing hi-tech products. However, existing research about higher education's contribution to sustainable development focuses on how to react to the requirement of sustainability development [3,4], how to construct an ecological environment on campus [5–7], or how to prepare future generations to address sustainability problems through curriculum [8,9] and teaching [10]. Such research only reflects what universities have done for sustainable development and does not directly present how well they are doing and where they need to improve in the process. Although some universities have released reports on sustainable development, the performance of scientific research is only a very small part of it [11].

As a result of the importance of scientific research in modern universities, we must evaluate sustainability performance. At present, the evaluation indexes of scientific research from the World University Rankings, such as ARWU, the Times Higher Education Rankings, QS World University Rankings, and US News World University Rankings, often focus

on the absolute level of the output of scientific research without considering the idea of sustainable development. Against this background, the research is devoted to developing an analytical framework to evaluate the scientific research of universities based on the idea of Education for Sustainable development and the function of scientific research activity, which is helpful for universities to improve the sustainability performance of scientific research and make a greater contribution to the society.

The study is organized as follows. Section 2 presents a literature review on the idea of education for sustainable development, the universities' activities for sustainable development, and the evaluation of universities based on the idea of sustainable development. Section 3 describes an analytical framework based on the idea of Education for Sustainable Development (ESD) and introduces the methods used to calculate the sustainability of scientific research. Section 4 presents the and explains them. Section 5 makes conclusions and provide suggestions for universities on how to improve the sustainability of scientific research.

2. Research Background and Literature Review

2.1. Trajectory of the Concepts of Education for Sustainable Development

Before constructing the framework to evaluate the sustainability of scientific research of universities it is necessary for us to determine the connection between sustainable development and sustainability. The two are close but different concepts [12]. Some researchers consider sustainability as a way to achieve sustainable development, while others believe sustainable development is the way to achieve sustainability [13,14]. Sustainability is the balance between environmental, economic, and social pillars [15], and it often has impacts on them [16,17]. The current recognized definition of Sustainable Development is "meets the needs of the present without compromising the ability of future generations to meet their own needs" proposed in the Brundtland Report [18].

Education is seen as an effective tool to achieve sustainable development. Since 1972, education has been recognized as playing an important role in achieving sustainable development [19]. The concept of Education for Sustainable Development (ESD) has been issued, developed [20–22], and interpreted in many different ways [23]. In 2018, the United Nations Educational, Scientific and Cultural Organization (UNESCO) published a report about ESD, stating that Education for Sustainable Development is globally acknowledged as a powerful driver of change, empowering learners to make decisions and actions needed to build a just and economically viable society respectful of both the environment and cultural diversity [24]. The report pointed out the emergence and the development of the concept of ESD and highlighted the two flows of change, i.e., the development of ESD examining both the integration of sustainable development into education systems and how education has been embedded in the discourse of sustainable development [24].

From the flows of change of the concept of ESD and sustainability, it can be deduced that evaluating the sustainability of the education system should consider at least two aspects: whether the education activity follows the principle of sustainable development and how the education contributes to the sustainable development of society.

2.2. Studies on the Universities' Activities for Sustainable Development

In higher education, the concept of sustainable development has attracted the attention of university administrators, and universities have started realizing their critical role in creating a sustainable future [25]. As a result, universities are starting to support sustainable development and make great efforts from teaching, scientific research, and contribution activities to social development.

As for the activity of teaching, universities are paying attention to environmental education [26] and directly teaching about sustainable development through the curriculum. Some universities have designed sustainability curricula [27] or incorporated sustainable development goals into the curriculum [28]. Students who join the class pay close attention to knowledge related to sustainable development [29] and develop environmentally, so-

cially, and culturally responsible attitudes [30]. In this way, graduates who may be potential leaders in the future may become concerned about the sustainable development of society. Some universities are committed to changing the curriculum by including new modules to strengthen content related to sustainable development [31] and stressing extension of the sustainable development curriculum [32,33]. However, studies have shown that they provide insufficient support for the principles and goals of sustainable development [34,35].

As for the activity of scientific research, universities are devoted to promoting sustainable development by several practices, including establishing sustainable development research institutes, providing funds for sustainable development research, and applying sustainable development research content in teaching [36]. This not only includes research projects, such as the Green Technology Project implemented by Malaysia [37], and the Research Framework Programme for Sustainable Development implemented by the German government [38], but also includes research practice such as the implementation of solar energy schools [39] and the utilization of open and remote learning [40]. In addition, universities try to control research orientation to support sustainable development. For instance, the University of Washington, the University of Oxford, and the University of Cambridge have discontinued and withdrawn research investments in traditional energy sources and are paying more attention to the research investment in renewable energy [41,42].

As for the contribution to social development, universities have always tried to support sustainable development by cooperating with stakeholders to set up science laboratories and bring benefits to the local economy [43], participating with governments to improve the condition of the environment and economy [44–46], helping public services to achieve sustainable development goals [47].

To sum up, universities takes several actions to support sustainable development and have a significant influence on society. However, there is seldom research aiming to evaluate the sustainability performance, especially the sustainability of scientific research.

2.3. Studies on Evaluation of Universities Based on the Idea of Sustainable Development

Research on the evaluation of universities for sustainable development has focused on whether universities integrate sustainable development into education systems. Some research has shown that universities have developed several tools for sustainability assessment [48,49], which mainly focus on environmental sustainability [11,45]. Other researchers developed an evaluation framework from the economy, equity, equality, and some other aspects relevant to sustainable development [50,51]. The assessment indicators used in the research, such as the number of enrolled female students, funding stability, and number of patents, are all related to the element and function of educational activity. This indicates that constructing a framework to evaluate the sustainability of a university needs to consider the idea of sustainable development and the element and function of educational activity.

At present, there are university ranking, such as ARWU, the Times Higher Education Rankings, QS World University Rankings, US News World University Rankings, which focus only on output without considering the idea of sustainable development. This study aims to develop an evaluation index system based on the idea of ESD, especially considering the flows of change of the concept.

3. Analytical Framework and Methods

UNESCO pointed out that ESD is a developing concept and highlighted two flows of change: the development of ESD examining both the integration of sustainable development into education systems, and how education has been embedded in the discourse of sustainable development [24]. In terms of the concept of ESD and the two flows of change, our study considers that the sustainability of scientific research of universities should consider at least two aspects. First, whether the university integrates sustainable development into their education systems. From this aspect, the analytical framework needs to consider the sustainable trend of scientific research, whether the principle of

sustainable development is followed in the scientific research of the university, and make sure it does not waste resources. Second, how does the university embed in sustainable development? From this aspect, the analytical framework needs to consider the sustainability of scientific research contributions to society. Besides the concept of ESD, it should be noted that scientific research itself can directly produce knowledge about sustainable development by publishing articles. From this aspect, the analytical framework needs to consider research performance related to the topic of sustainable development. Based on these considerations, the dimensions of the analytical framework are shown in Figure 1.

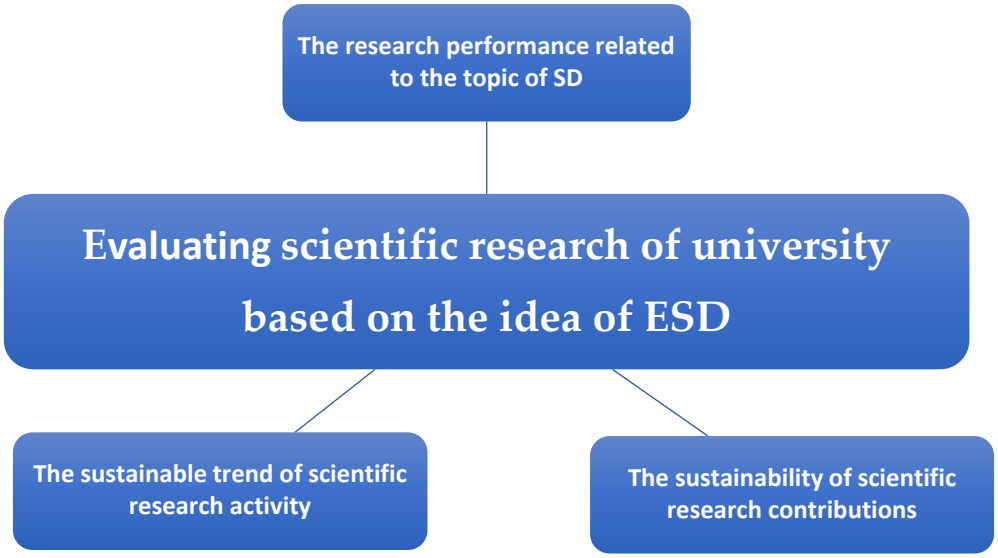

Figure 1. Dimensions for evaluating scientific research of a university based on ESD.

The evaluation framework can also be extracted from three dimensions. First, the sustainable development principle requires universities to reduce resource waste when conducting scientific research. Second, the scientific research activity should make a sustainable contribution to social development. Third, universities should focus on research related to the topic of sustainable development and improve their research performance. To realize the evaluation of the three dimensions, different measurements are designed and proposed in this study.

3.1. Evaluation of the Sustainable Trend of Scientific Research

Scientific research activities are correlated with input of human and financial resources and the quantity and quality of research output. If universities use fewer human and financial resources to produce more research output, they can keep a positive sustainable trend in the future and realize the sustainable development of scientific research. In existing studies, this state can be reflected by calculating the resource redundancy of scientific research. Many scholars adopt the input-output efficiency model based on Data Envelope Analysis (DEA) to measure the state [52]. DEA is also widely used to judge whether scientific research has a positive sustainable trend [53,54]. During the process of scientific research activity, only the human and financial resources invested into scientific research activities can be controlled, so the DEA model based on cost considerations (Cost-DEA) was adopted in this study. Scientific research of universities aims to produce knowledge, and the process is also beneficial for student cultivation and social development. For example, professors could share the advanced research progress in class or instruct the students to experiment; they could also transfer their research findings into products to meet social needs. In this study, full-time teachers, and funds for scientific research are taken as input variables, and the number of Ph.D. graduates, the number of research papers, and the amount of science and technology transformation are taken as output variables.

They are used to calculate the input-output efficiency of scientific research and present the sustainable trend of scientific research.

3.2. Evaluation of the Research Performance Related to the Topic of Sustainable Development

In terms of the evaluation of research performance related to the topic of sustainable development, previous studies have often used content analysis. For example, the keywords 'sustainable development' [55], 'sustainability strategy' [56], and some other terms were searched to analyze the research papers related to the topic of sustainable development. To include the research paper related to sustainable development as far as possible, this study reviewed the literature involving the keyword "sustain" among all research papers. Scival is a statistical tool used in scientific research developed by Elsevier. It can search the literature on specific topics and evaluate their performance. Based on the Scival database, the research papers related to sustainable development were searched. The performance of the research papers can be reflected by their quantity and quality. Quantity can be measured by the number of papers and quality by the index Field-Weighted citation index (FWCI).

3.3. Evaluation of the Sustainability of Scientific Research Contributions

Teaching, research, and contribution to society are the three main functions of modern universities [57,58]. Scientific research activity aims at knowledge production, and the process is also beneficial for student cultivation and social development. For knowledge production, published papers can disseminate knowledge in society and help others to solve a relevant problem. For student cultivation, doctoral students cultivated through scientific research may continue to do research and make a great contribution to society. For contribution to social development, the benefits transformed from knowledge production reflect the social contributions of scientific research. In this study, the growth level and the level of student cultivation, research publications, and science and technology transformation are used to calculate the sustainability of scientific research contributions. Since sustainability focuses more on growth, log-transformation was used to control the influence of the level. The calculation formula is as follows:

$$\text{Level\_Sustain} = \text{Ln}(\text{Level\_Amount}) \times (1 + \text{Level\_AverageGrowth}) \quad (1)$$

where Level_Sustain is the sustainability of each scientific research function, Level_Amout is the specific value of all dimensions of scientific research and Level_AverageGrowth is the average annual growth level of all dimensions of scientific research.

In conclusion, a three-dimensional evaluation framework for scientific research was constructed. The framework includes the sustainable trend of scientific research, the sustainability of scientific research contribution, and the research performance related to the topic of sustainable development. The analytical framework and methods are shown in Table 1.

Table 1. Evaluation Framework for the sustainability of Scientific Research.

Evaluation Dimension	Evaluation Index	Evaluation Method
Sustainable trend of scientific research	Research efficiency of scientific research	The efficiency of scientific research is calculated with the Cost DEA model
Research performance related to the topic of sustainable development	Quantity of research papers related to the topic of sustainable development	Based on the Scival database, the papers containing "sustain" are searched and the papers on sustainable development are counted.
	Quality of research papers related to the topic of sustainable development	The field weighted cited index of papers on sustainable development is calculated.

Table 1. *Cont.*

Evaluation Dimension	Evaluation Index	Evaluation Method
Sustainability of scientific research contributions	Number of the Ph.D. graduate and average annual growth level	The number of Ph.D. graduates is counted. The average growth rate is calculated.
	Number of research papers produced and average annual growth level	The research papers in Chinese and foreign languages published are counted. The growth rate is calculated.
	Amount of science and technology transformation and average annual growth level	The amount of science and technology transformation are counted. The growth rate is calculated.

To compare the sustainability of scientific research of each university, a statistical index method was used. In the process, to verify the stability of research results, the average weight method and entropy weight method were used for weighting calculations of all variables. If the two results are highly correlated, this proves the framework is stable and effective.

4. Objects of Study, Data Description, and Calculation Results

Sustainable development means a positive development trend. If a university follows the principle of sustainable development and makes a sustainable contribution to society, it should be a reputable university. China's comprehensive national strength and influence are rising, and the sustainability its universities should have a great influence on the international world. China now has released a plan to construct world-class universities in 2014. The construction of universities within the plan is selected by considering their comprehensive strength, especially their scientific research performance. The plan has five-year cycles and the first cycle ended in 2020. Based on the above reasons, the 42 world-class universities in China were selected as research objects and their research performance from 2016 to 2020 was evaluated.

4.1. Objects of Study

Among the universities that are striving to become world-class universities in China, the data on the National University of Defense Technology (NUDT) were not published and could not be found. The objects of this study included Peking University, Beihang University, Beijing Institute of Technology, Beijing Normal University, Dalian University of Technology, University of Electronic Science and Technology of China, Northeastern University China, Southeast University, Nanjing, Fudan University, Harbin Institute of Technology, Hunan University, East China Normal University, South China University of Technology, Huazhong University of Science and Technology, Jilin University, Lanzhou University, Nanjing University, Nankai University, Tsinghua University, Xiamen University, Shandong University, Shanghai Jiao Tong University, Sichuan University, Tianjin University, Tongji University, Wuhan University, Xi'an Jiaotong University, Northwestern Polytechnical University Xian, Northwest Agriculture and Forestry University, Xinjiang University, Yunnan University, Zhejiang University, Zhengzhou University, Ocean University of China, University of Science and Technology of China, China Agricultural University, Renmin University of China, Central South University, Sun Yat-Sen University, Minzu University of China, and Chongqing University.

4.2. Data Description and Analysis

Three dimensions were included in the evaluation of the sustainability of scientific research of universities. The evaluation indexes involved including the number of papers related to the topic of sustainable development, the impact of papers related to the topic of sustainable development, the number of doctoral graduates, the number of scientific research papers, the amount of science and technology transformation, the number of full-time researchers, and the amount of funds for R&D invested.

4.2.1. Papers Related to the Topic of Sustainable Development

The average number of papers related to the topic of sustainable development from 2016 to 2020 was 24.17. The FWCI of the papers was 1.48. The results and standard deviations (SD) in Table 2 show that there are significant differences between universities.

Table 2. Descriptive analysis of the performance of the paper related to the topic of Sustainable Development.

2016–2020	Average	SD
Number of the Paper	24.17	25.18
FWCI of the Paper	1.48	1.23

4.2.2. Ph.D. Graduates

The number of Ph.D. graduates increased from 2016 to 2020, but the growth decreased significantly in 2020. The possible reason may be related to COVID-19, resulting in a decrease in the number of Ph.D. graduates in that year. The SD of performance of different universities in Table 3 indicates that there are significant differences between universities.

Table 3. Descriptive Analysis of Number of Ph.D. graduates.

Year	Average	SD
2015–2016	740.66	435.30
2016–2017	782.34	469.68
2017–2018	819.22	472.32
2018–2019	849.46	500.41
2019–2020	627.39	458.53

4.2.3. Research Papers

As shown in Table 4, the total number of research papers published by universities was steadily increased from 2016 to 2020. The number showed a slight decrease in 2020, which might also be caused by the influence of the COVID-19 on scientific research. Similar to the number of Ph.D. graduates, there are significant differences between universities.

Table 4. Descriptive Analysis of Research Papers.

Year	Average	SD
2015–2016	740.66	435.30
2016–2017	782.34	469.68
2017–2018	819.22	472.32
2018–2019	849.46	500.41
2019–2020	627.39	458.53

4.2.4. Amount of Science and Technology Transformation

Data in Table 5 show that the amount of science and technology transformation were wavelike, and there were significant differences between universities, correlated with the transformation ability of scientific research and correlated with the disciplinary structure of the universities. The scientific research outputs from science and engineering and comprehensive universities often have higher market value, while that from humanities and social sciences universities have relatively lower market value.

4.2.5. Full-Time Teachers

The number of full-time teachers reflects the human resources invested into scientific research activity. As shown in Table 6, the number of full-time teachers was quite stable with a five-year average increase of 220. The SD of full-time teachers by universities also narrowed, indicating that the scale of full-time teachers in universities was relatively stable.

Table 5. Descriptive Analysis of Amount of Science and Technology Transformation.

Year	Average (Thousand Yuan)	SD
2015–2016	27,347.27	61,857.34
2016–2017	27,972.73	61,044.16
2017–2018	41,460.22	79,036.23
2018–2019	22,105.66	29,986.39
2019–2020	34,804.98	46,681.44

Table 6. Descriptive Analysis of Number of Full-time Teachers.

Year	Average	SD
2015–2016	2727.537	934.8589
2016–2017	2767.659	926.6927
2017–2018	2816.39	911.0147
2018–2019	2866.22	900.7491
2019–2020	2943.073	917.6103

4.2.6. Funds for R&D

Funds for R&D reflect the level of scientific research funding investment. Data in Table 7 show that the amount of funds for scientific research in universities kept increasing. On the one hand, this is related to increasing attention paid to scientific research. On the other hand, it is associated with the world-class university construction plan to provide more stable and sufficient funding income for universities. The SD values show that there were significant differences in funding level among universities.

Table 7. Descriptive Analysis of Amount of Funds for R&D Expenditure.

Year	Average (Thousand Yuan)	SD
2015–2016	949,609	676,087.5
2016–2017	1,061,447	719,090.4
2017–2018	1,252,786	881,047.2
2018–2019	1,379,899	1,029,468
2019–2020	1,403,085	1,027,545

4.3. Sustainability of Scientific Research

According to the three dimensions of the sustainability of scientific research, the results of each dimension were calculated and represented in the form of diagrams. The statistical index method and average weighting method were used to calculate the correlation between the result of sustainability evaluation of scientific research and the result of scientific research evaluation in the ARWU 2021.

4.3.1. Evaluation of Sustainable Trends of Scientific Research Activity

The sustainable trend of scientific research is reflected by calculation of the input-output efficiency based on DEA. The results of input redundancy in the calculation results reflects problems in R&D personnel and financial input.

According to the results from 41 universities, 28 universities are in a positive trend, in which the resources invested are completely utilized or increasing resource input can bring more benefit. This means more than half of these universities can contribute more output by improving resource investment. However, it should be noted that from the results of technical efficiency, only eight universities are in a positive trend. This means that the teacher and funding structure of 20 of the 28 universities can be optimized. Such universities should improve the quality of teachers and funding utilization efficiency.

For the 13 universities with decreasing scales, their scientific research efficiency is low, indicating that part of the human and financial resources invested into these universities are wasted. Especially for Jilin University, Northwest A&F University, Shandong University, and Wuhan University, although their technical efficiency level has reached a positive trend, low efficiency of scientific research is caused by waste of resources. Such universities need to reduce the scale of teachers and control expenditures on scientific research. The efficiency, pure efficiency, and scale efficiency of scientific research of each school are shown in Figure 2.

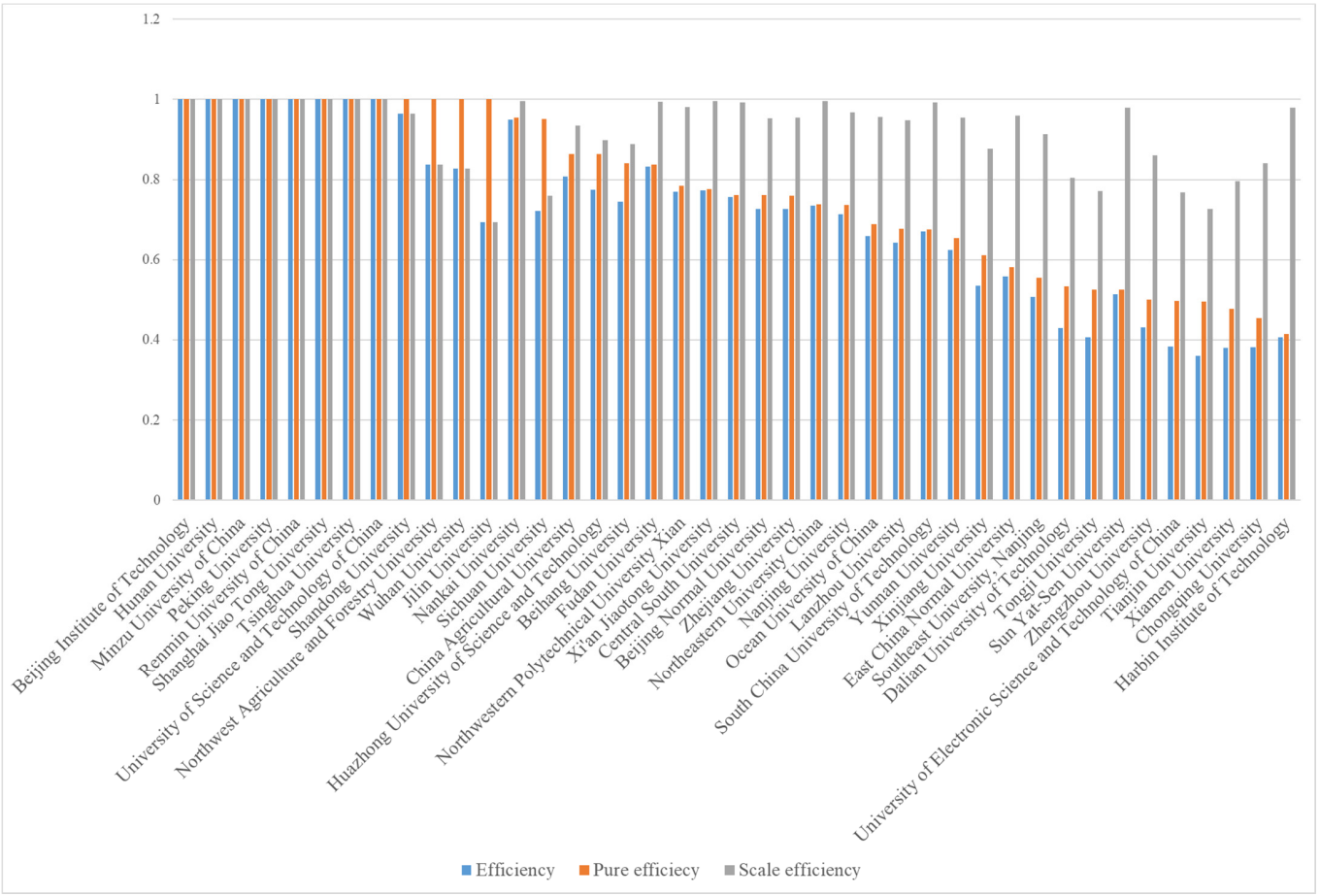

Figure 2. Sustainable trend of scientific research activity.

4.3.2. Evaluation of Research Performance Related to Sustainable Development

Research performance can be evaluated by the quantity and quality of research papers related to the topic of sustainable development. In terms of the number of research papers, Chongqing University, Zhejiang University and Huazhong University of Science and Technology have ranked the top three, and have published 128, 80, and 74 relevant papers, respectively. The quality of the papers published by the three universities also exceeds the global average level, and the FWCI is 1.49, 2.29, and 1.75, respectively. However, it should be noted that some universities, such as Yunnan University, Nankai University, Lanzhou University, Xinjiang University, Minzu University of China, and Northwest A&F University, did not publish any paper related to sustainable development.

The number of papers related to the topic of sustainable development cannot be reflected by universities in China alone. Therefore, the number of papers published by America and Britain was counted. The results in Figure 3 show that Purdue University published the most papers (23) on the topic in America during 2016–2020. The University of Nottingham published the most papers (19) on the topic of sustainable development in

Britain. The results show that the average number of papers on sustainable development published by universities in China is greater than that published by the best performing universities in America and Britain. This indicates that Chinese universities are paying great attention to research related to the topic of sustainable development.

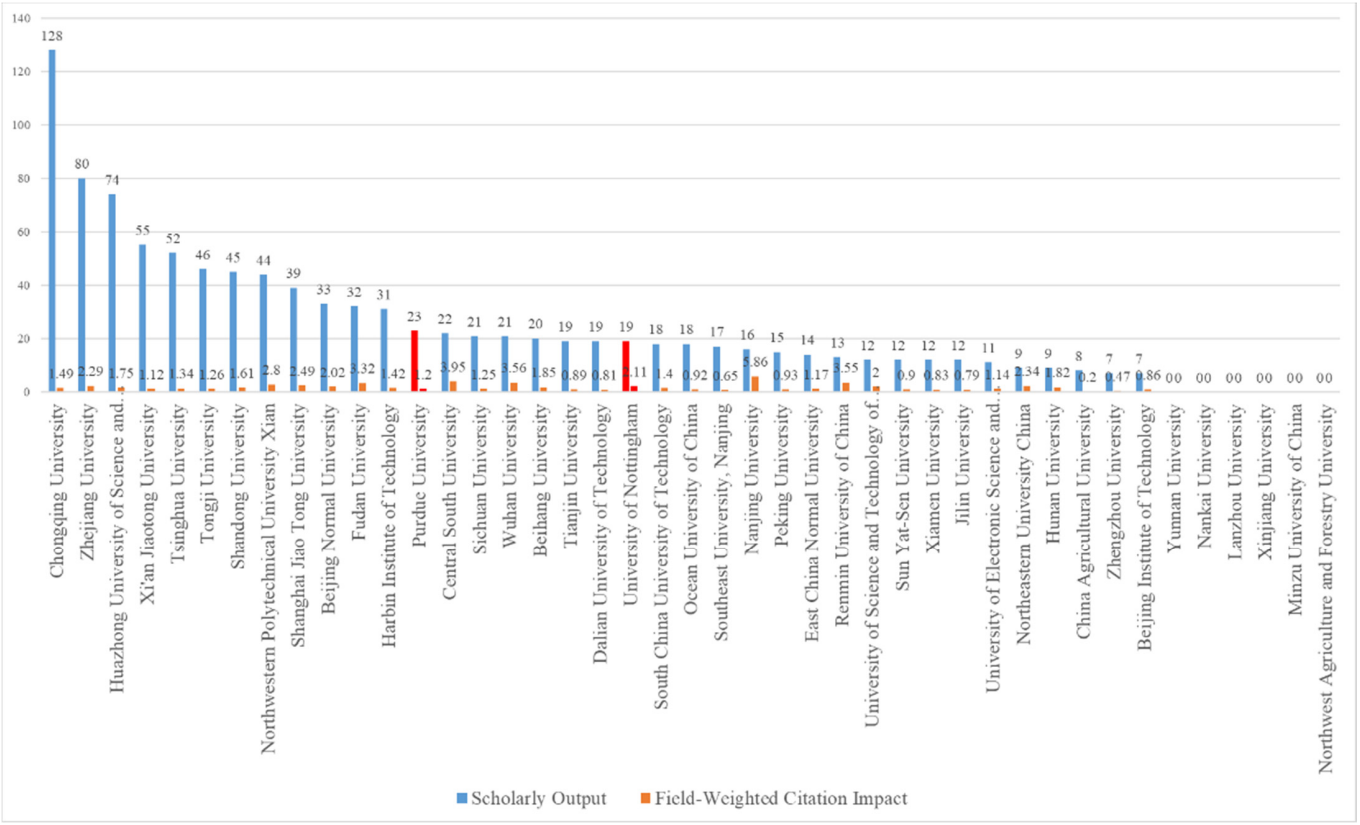

Figure 3. Number and FWCI of Papers related to the topic of Sustainable Development. The retrieval format for papers on sustainable development research is the subjects containing keywords 'sustainable', 'sustainability', or 'sustain'.

4.3.3. Evaluation of the Sustainability of Scientific Research Contributions

The sustainability of scientific research contributions includes the contribution of Ph.D. graduates, research papers, and amount of science and technology transformation. The results of the analysis of the number of doctoral graduates in Figure 4 showed that only 11 of the 41 universities of the annual growth rate of the number of Ph.D. graduates was positive. Although the absolute level of some universities is higher, the fluctuations in the Ph.D. graduates reflect its unsustainable trend. It should be pointed out that was mainly due to the period of 2019–2020. This may be caused by the great influence of the COVID-19 in China in 2020. This reminds universities to be alert to the external impact of public emergencies that may greatly affect the sustainability of universities.

Different from the number of Ph.D. graduates, the output of research papers had good sustainability. As shown in Figure 5, among 41 universities, the research paper output of 34 universities was increasing. The output of English research papers of all these universities was increasing. The average increase of Chinese and English papers was 2.3% and that of English papers 12.36%. Zhengzhou University, Yunnan University, Minzu University of China, and Xinjiang University had the fastest increase of English papers. This indicates that a great deal of attention was paid by the Chinese Government to higher education in underdeveloped areas, which stimulated knowledge production of universities in these areas. However, the growth level decreased significantly in 2020, which might be related to the influence of COVID-19.

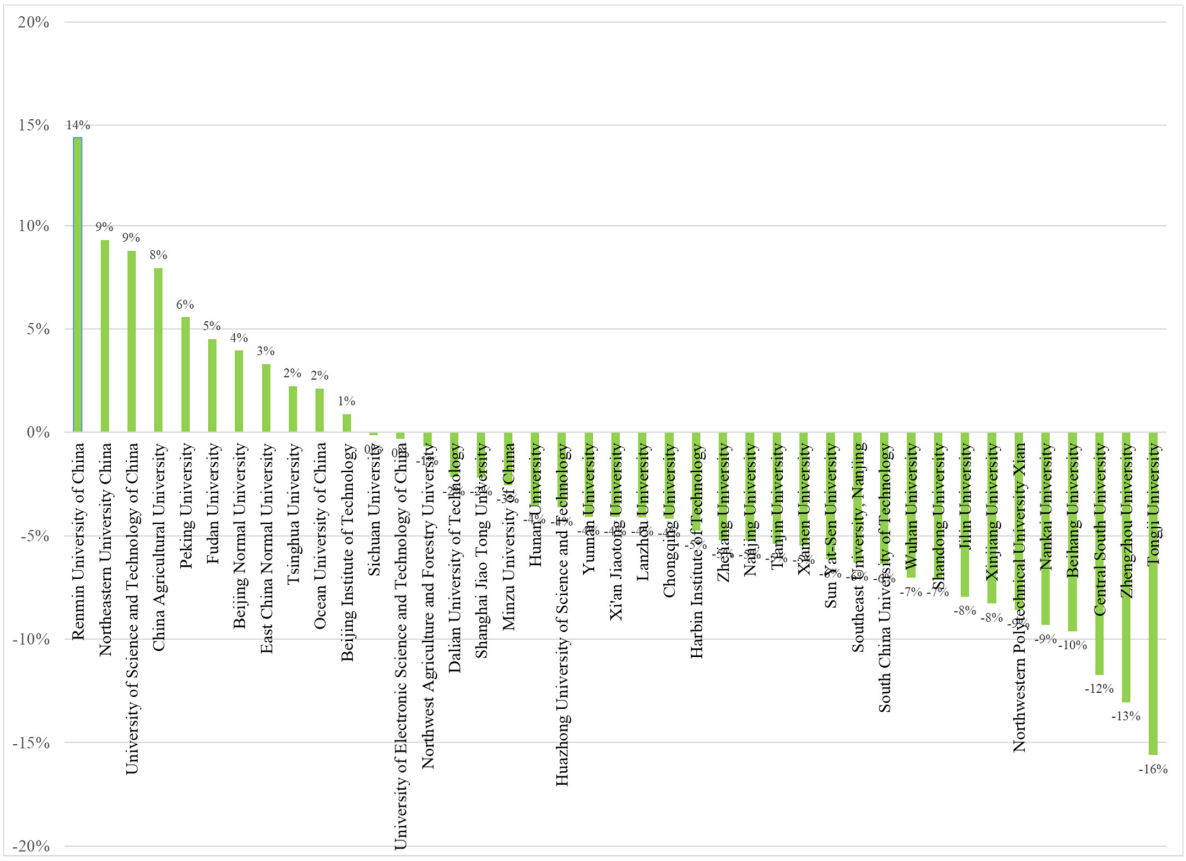

Figure 4. Overall sustainable growth of Ph.D. graduates.

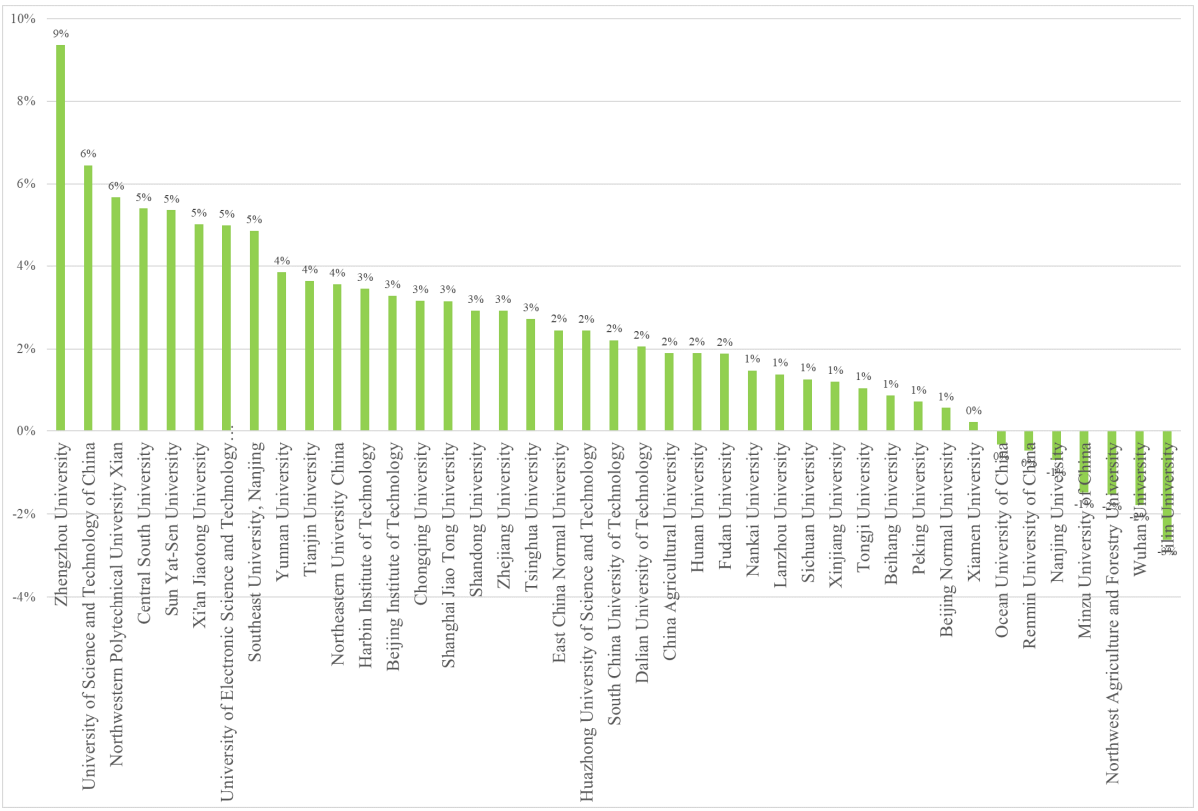

Figure 5. Overall sustainable growth of Research Paper Output.

Sustainability of the contribution to social development was also stable. The average percentage of sustained growth reached 314.75%, indicating that the contributions made by Chinese universities to social development are increasing and are at a high sustainable level. As shown in Figure 6, among the 41 universities, only the growth of Minzu University of China and Xinjiang University was zero and that of South China University of Technology was negative. The poor performance of the Minzu University of China is due to its research focus on the field of humanities and social sciences. The contributions made by Xinjiang University to social development are limited because of its economic condition. For the South China University of Technology, although the growth was negative, the absolute level of transformation was still high.

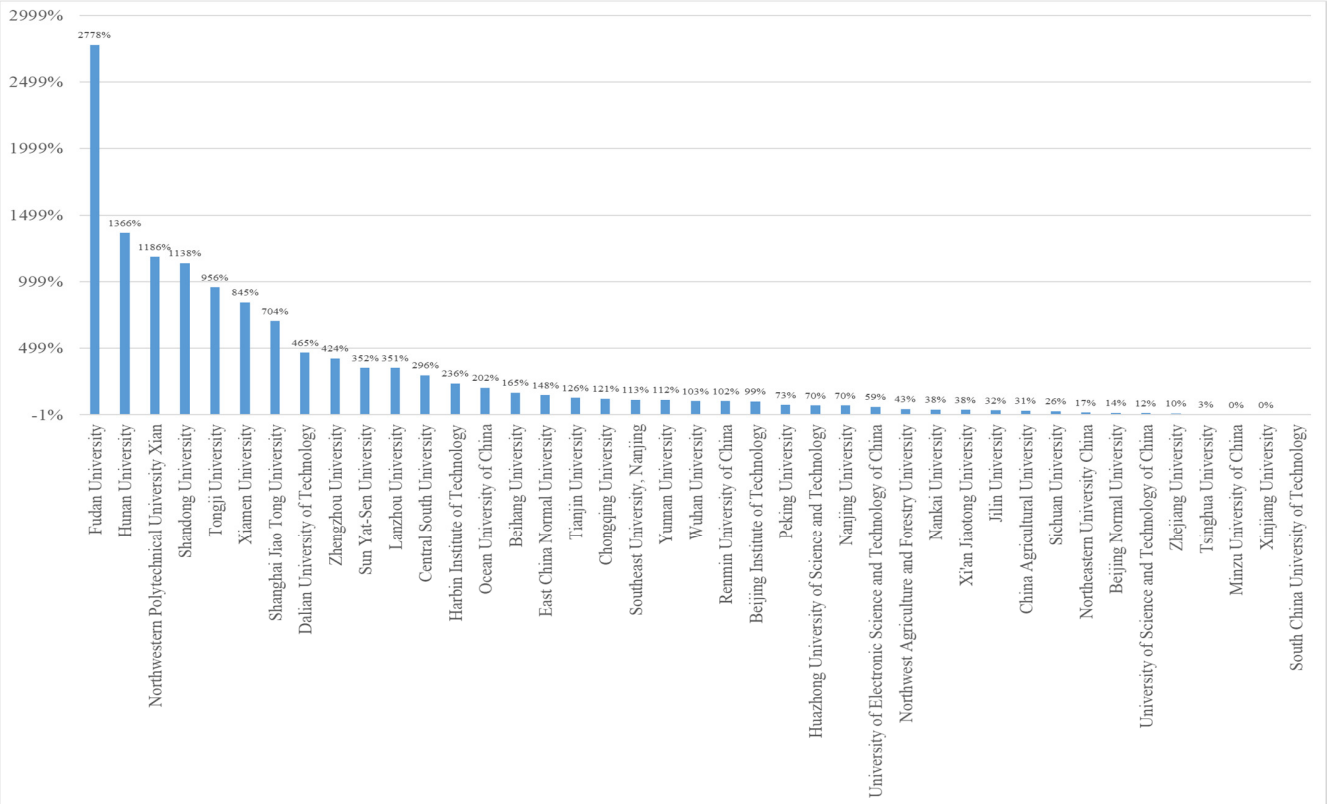

Figure 6. Overall sustainable growth of social contributions.

4.3.4. Evaluation of Overall Sustainability of Scientific Research

To present the overall sustainability of scientific research of universities, the equal weight method and entropy weight method were used in this study. The result of the sustainability of scientific research and the scientific research performance calculated by ARWU was also used to prove the validity of the evaluation index system.

As shown in Figure 7 and Table 8, the correlation coefficient between the calculated results by the entropy weight method and the equal weight method, respectively, was 0.98, indicating that the calculated results of the evaluation index system established were stable. However, it should be noted that the correlation coefficients between the results of the overall sustainability of scientific research calculated by entropy weight method, equal weight method, and the ARWU 2021 were, respectively, 0.45 and 0.37, indicating a moderately positive correlation. The specific results are listed in Table 8 below.

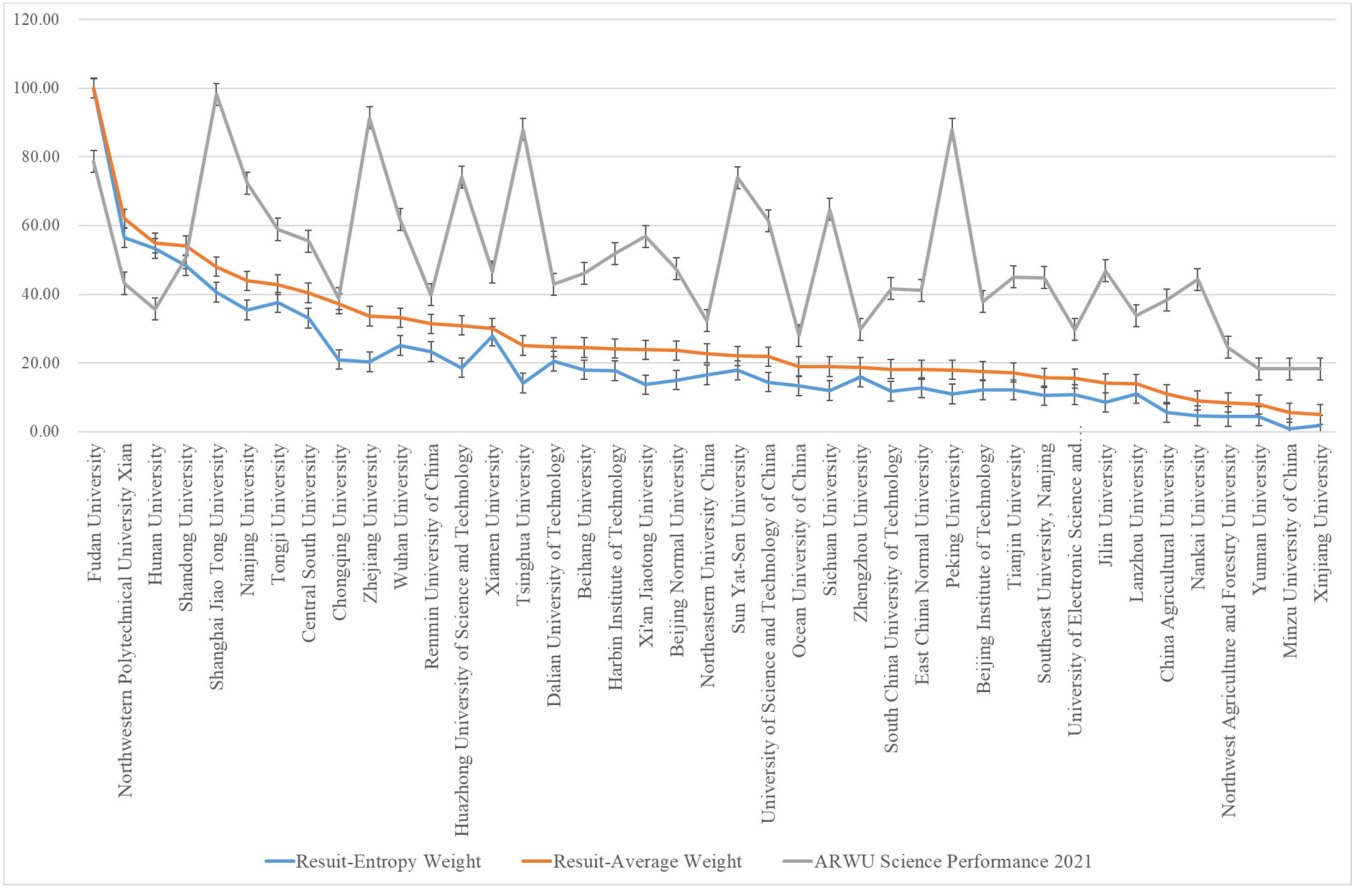

Figure 7. Overall Sustainable Development Level of Universities.

Table 8. Correlation analysis.

Variable	Result-Entropy Weight	Result-Average Weight	ARWU Science Performance 2021
Result-Entropy Weight	1		
Result-Average Weight	0.985 **	1	
ARWU Science Performance 2021	0.374 *	0.452 **	1

* $p < 0.05$, ** $p < 0.01$.

The results in the Table 8 show that the scientific research performance of universities in the future is significantly correlated with the sustainability of scientific research. However, the two factors were only moderately positively correlated, the reason for which is that the existing scientific research evaluation system focuses more on the absolute number of scientific research outputs and does not conform to the idea of sustainable development.

5. Conclusions and Discussion

5.1. Conclusions

This study developed an analytical framework based on the idea of ESD and scientific research activity. The framework includes the dimensions of the sustainable trend of scientific research, the research performance related to the topic of sustainable development, and the sustainability of scientific research contributions. The evaluation results based on the evaluation framework have a positive correlation with the result of the ARWU evaluation in 2021, which indicates the evaluation index system is valid. Based on the analysis, the following conclusions can be drawn.

First, most of the world-class universities in China showed a sustainable trend in scientific research. The result of efficiency analysis indicated most universities are in a positive

trend and they make full use of the inputting resource. In the future, universities should also try to improve the research ability of researchers and maintain the sustainable trend.

Secondly, world-class universities in China attach importance to doing research related to the topic of sustainable development, and the average output of the research papers is higher than the best universities from the UK and USA. This shows that China's development emphasizes sustainability and high quality, which requires the universities to conduct research about sustainable development as much as possible with benefits to the development of the whole world.

Third, the sustainability contribution of scientific research is increasing. The number of Ph.D. graduates, research papers, and the amount of science and technology transformation is increasing overall. Although some universities' performances were not stable, they may improve their condition after the outbreak of COVID-19.

5.2. Discussion

At present, the overall sustainability of scientific research of world-class universities in China is positive, but universities around the world are facing challenge from the COVID-19.

Previous studies showed that because of the COVID-19 pandemic, universities can no longer provide large-scale funding for projects [59] and some universities directly or indirectly asked teachers to take leave. Many faculty members were laid off [60]. A great negative impact resulted to scientific research in the field of medicine and design because experimental facilities are needed for research and some research was interrupted [61]. The performance of universities striving to become world-class universities in China in 2020 was also significantly affected by COVID-19. The number of Ph.D. graduates, research production, and contribution to social development through scientific research in multiple universities decreased significantly.

Against this background, universities should consciously adjust by strengthening scientific research on sustainable development and continue to increase their contributions to social development. However, this study concluded that universities have not paid much attention to research related to the topic of sustainable development. Besides, the scientific research efficiency of some universities is low, indicating that these universities failed to follow the principle of sustainable development during their scientific research activity. This is consistent with the point of view that 'most higher education institutions still have not implemented sustainable development practices' [62]. On the one hand, since researchers do not regard sustainable development as the primary task of universities [63] and many higher education stakeholders resist sustainable changes [64–66], the management of higher education no longer focuses on long-term scientific research benefits, but short-term benefits [67]. On the other hand, the cost and relevant risk for higher education in implementing sustainable development has increased due to inadequate financial resources and funds. As a result, the benefits from implementing sustainable development by universities are insufficient [68]. In such a case, the Chinese Government and universities attempted to alleviate this phenomenon by adjusting evaluation policies for scientific research [69], but this doesn't seem to work. Research has also pointed out that higher education institutions have not taken systematic methods to include sustainable development into the development planning of higher education, and that a single sustainability initiative has gone far beyond the sustainable development strategies and policies specified by universities [56].

Against this background, universities should take action to achieve sustainable development by integrating the principle of sustainable development into scientific research activity. Leaders of universities should actively take in the principle of sustainability in the development strategy of higher education institutions [66] and ensure sustainable development becomes a golden thread running through the university [62]. Specific measures are considered below.

First, universities can initiate relevant declarations and initiatives jointly with the government and other social organizations. Previous studies have shown that declara-

tions, charters, and external partnerships play a key role in promoting sustainable development changes and can ensure that universities keep their promise of sustainable development [70,71].

Second, in the process of carrying out scientific research, attention should be paid to important issues associated with sustainable development and strengthen research related to the topic of sustainable development. Universities should also pay attention to spreading of the idea of sustainable development throughout classroom teaching their students to focus on the sustainability of studies in the future.

Third, researchers should pay attention to the sustainability of their research. This sustainability is reflected in not wasting human and financial resources and not harming the environment. Moreover, it should be ensured that studies are conducive to social progress.

Fourth, universities and third-party evaluation organizations should appeal for the inclusion of the principle of sustainable development into the evaluation framework. The current world university rankings, including ARWU, the Times Higher Education Rankings, QS World University Rankings, and US News World University Rankings, stress the evaluation of the absolute level of scientific research output, neglect the efficiency of scientific research, do not consider the idea of sustainable development. Such valuation orientation goes against universities in formulating sustainable development strategies. In the future, relevant organizations should try to include the principle of sustainable development in the concept of the evaluation, and guide universities to focus on sustainable development to make sustainable contributions to social development.

This study has some deficiencies: First, the retrieval results from the Scival database were used to measure the research topic related to sustainable development and may be not comprehensive. Second, when evaluating the sustainable trend of scientific research activities, only human and financial indexes were considered due to data limitations. The materials consumed and the environmental pollution caused by scientific research could also be considered during scientific research activities. More indexes associated with ESD may be developed in a future study to analyze the sustainability of scientific research in universities.

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