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Analysis of Total Factor Productivity of the Integration of Industry and Instruction in China's Universities

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Abstract:

The integration of industry and instruction is an important part of the undergraduate level vocational instruction system. It is not only for the industrial demand for high-level technical talents, but also an important measure to serve the industry and society in the process of running a university. This paper selects the relevant data of 31 provinces (cities / autonomous regions) in China from 2010 to 2019, and uses Data Envelopment Analysis and Malmquist productivity index model to analyze the total factor productivity of economic input of industry instruction integration. The analysis results show that the relevant investment of universities and enterprises in the integration of industry and instruction has maintained a stable growth, but the productivity of the integration of industry and instruction funds in undergraduate vocational instruction is low, and there is a large room for improvement. Over the past decade, the productivity index of relevant funds has gradually stabilized from a large fluctuation trend.

Keywords*: Integration of industry and instruction, DEA-Malmquist method, Total factor productivity.*

I. INTRODUCTION

The General Office of the Ministry of Education of China issued Circular on the measures for the administration of specialty setting of vocational education at undergraduate level (Trial), it stressed that relevant departments should establish a new development concept, adhere to demand orientation and service development, these majors should comply with the new round of scientific and technological revolution and industrial reform, follow the laws of vocational education and talent growth, and meet the needs of students' all-round and sustainable development [1]. The trial measures clearly stipulate that the proportion of double qualified teachers shall not be less than 50 percent, and make clear requirements for training projects and school enterprise cooperation. There are two concepts frequently mentioned in the field of education in China. They are applied undergraduate and undergraduate vocational education. The State Council has an implementation plan for vocational education reform, which does not distinguish

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between the two terms. From the perspective of specialty setting and talent training, "Applied undergraduate" pays attention to the social needs of majors, while "undergraduate vocational education" pays attention to the cultivation of students' professional quality. Nowadays, the original independent colleges of ordinary undergraduate universities have been reformed, and many independent colleges have merged with higher vocational colleges to establish new application-oriented undergraduate colleges. This general merger trajectory can also be regarded as the result of policy orientation, relying on the experience of independent colleges in running applied undergraduate majors, combined with the concept of vocational education in higher vocational and technical colleges. The merging model of schools and schools aims to achieve this goal: to run vocational education at the undergraduate level.

Vocational education at the undergraduate level is different from vocational education at the junior college level. It needs to combine the dual characteristics of vocational general education and undergraduate level to find the correct positioning. To understand the connotation significance and strategy of vocational education at undergraduate level, research needs to jump out of the thinking pattern of layered vocational education. Vocational education at undergraduate level is a major breakthrough in improving the system of modern vocational education in China. It contains the reconstruction of the development system and mechanism of vocational education in China [2]. The second is to study the performance of undergraduate vocational education and explore the input-output of this education. Universities are different from enterprises. Enterprises obtain intuitive input-output indicators with the help of production indicators and market feedback. Universities need to select appropriate input indicators from the aspects of teacher construction, project training, production, University and research, and analyze the output performance from the aspects of student employment, academic papers, training projects and so on [3].

The integration of industry and instruction is the in-depth cooperation between industry and education, and the in-depth cooperation between universities and industry enterprises to improve the quality of talent training [4]. In the undergraduate level vocational education system, universities need to cultivate comprehensive talents who meet the needs of social industry. The social function of universities emphasizes the interaction between them and enterprises on practical research [5]. Integration of science, education and industry based on higher education establishments is a multi-level process, which includes uniform educational space and use of different innovative techniques and methods of teaching. It can be said that the development of universities in the integration of industry and instruction is not only the embodiment of the social influence of universities at the level of industrial R & D, but also the display of the training ability of applied talents in universities. The research on the performance of integration of production and education in various regions universities is of great significance for the study of undergraduate vocational education. In terms of input, the data of human input and financial input are used. In terms of output, the data of the number of graduates, enterprise performance, relevant scientific research achievements and so on are used; Using Data Envelopment Analysis and Malmquist productivity index model, this paper analyzes the total factor productivity of economic input integrated with industry and education.

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II. MODEL AND DATA SELECTION

2.1 Data Envelopment Analysis and Malmquist Index Model

Data envelopment analysis (DEA) is mainly used to evaluate the relative effectiveness of "decision-making units" with multiple inputs and outputs, also known as DEA effectiveness. It is to judge whether DMU is DEA effective according to the observed data of each decision-making unit (DMU). DEA method can analyze performance based on linear programming, so it can be used for decision analysis in the form of setting parameters and with the help of the software solution results of linear programming. The data envelopment analysis-BCC model is based on variable scale rate of return, and the obtained technical efficiency excludes the influence of scale. It can be decomposed into technical efficiency change and technical progress change. The change of technological efficiency means the impact of organizational management level on productivity, and the change of technological progress means the impact of science and technology on productive [6]. The result of DEA efficiency value is between 0-1. The higher the value, the higher efficiency level. Arrange the formula as follows:

$$\min \theta$$
$$\sum_{j=1}^{n} x_j \lambda_j \leq \theta x_0$$
$$\sum_{j=1}^{n} y_j \lambda_j \geq y_0$$
$$\sum_{j=1}^{n} \lambda_j = 1$$
$$\lambda_j \geq 0, j = 1,2,\ldots,n$$

θ Represents valid data for the decision unit (DMU). Assuming that there are j decision units, for the input situation, the input vector available matrix: $x_j = (x_{1j}, x_{2j}, \ldots, x_{mj})^T$, for the output situation, the output vector available matrix: $y_j = (y_{1j}, y_{2j}, \ldots, y_{kj})^T$, where x_{ij} (i=1, 2, …, m; j=1, 2, …, n) represents the input value of the i-th input in the decision-making unit numbered J and y_{rj}(r=1, 2, …, k; j=1, 2, …, n) represents the output value of the r-th output in the decision-making unit numbered J, λ_j is the weight coefficient.

Malmquist index is mainly used to dynamically analyze the efficiency of decision-making unit in DEA method. By using this method, the productivity change is calculated, and the calculation formula is as follows:

$$M_t(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_C^t(x^{t+1}, y^{t+1})}{D_C^t(x^t, y^t)}$$

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$$M_{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{1(x^{t+1}, y^{t+1})}{D_C^{t+1}(x^t, y^t)}$$

Where x_t and x_{t+1} respectively represent the input in period T and period T+1, y_t and y_{t+1} respectively represent the output in period T and period T+1, $Dc^t(x^t, y^t)$ represents the technical efficiency value of T period, while $Dc^t(x^t, y^t)$ is technical efficiency value of T+1 period, $Dc^{t+1}(x^t, y^t)$ is technical efficiency value of T period, $Dc^{t+1}(x^{t+1}, y^{t+1})$ represents the technical efficiency value of T+1 period.

2.2 Research Perspective and Data Selection

The purpose of this study is to examine the scope of undergraduate vocational education in a specific setting. The change in total factor production in the Malmquist index in this study refers to the change in the resource allocation performance of universities in the integration of industry and instruction in vocational education. The input indicators are closely linked to the integration of industry and instruction, looking for the correlation point between the university running mode and economic development of China, such as relevant teacher investment, practice platform fund investment, etc. the output indicators are mainly analyzed based on the statistical results with certain economic benefits, such as published papers, adopted research and consulting reports, and technology transfer. In terms of spatial dimension, the integration performance of industry and education should have a universal scope. Therefore, this paper takes various national statistical yearbooks since 2010-2019 as the data source for statistical analysis. See TABLE I. for details.

TABLE I. Industry education integration indicators of undergraduate vocational education

Indicator type	Name	Unit	Indicator Source	Remarks
Input Index	number of full-time double qualified teachers	person	China Education Statistics Yearbook	Human resources investment
	number of part-time double qualified teachers	person	China Education Statistics Yearbook	Human resources investment
	education expenditure per student	yuan / person	China educational finance statistical yearbook	Student training funds
	R & D funds of colleges and universities (enterprises)	10000 yuan	China Science and technology statistical yearbook	Enterprise capital investment
Output Indicators	Number of undergraduate graduates	person	China Statistical Yearbook	Training results
	Operating income of industrial enterprises	100 million yuan	China Statistical Yearbook	Enterprise performance
	Publish scientific papers	articles	China Science and technology statistical yearbook	Scientific and technological achievements

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	Publishing scientific and technological works	articles	China Science and technology statistical yearbook	Scientific and technological achievements
	Number of patent applications	piece	China Science and technology statistical yearbook	Scientific and technological achievements

III. DATA ANALYSIS

3.1 Overall Analysis of Input and Output

In order to better view the change trend of the overall input and output related to the integration of industry and instruction, the relevant data of the university are put into the same dimension through sorting. In order to better compare the change trend of input and output vertically, the overall change trend is viewed from the two dimensions of human investment and capital investment.

In terms of human investment, the number of full-time and part-time dual qualified teachers is added and summarized. In terms of output, it covers the number of undergraduate graduates, published scientific and technological papers, published scientific and technological works and patent authorization, as shown in Fig 1.

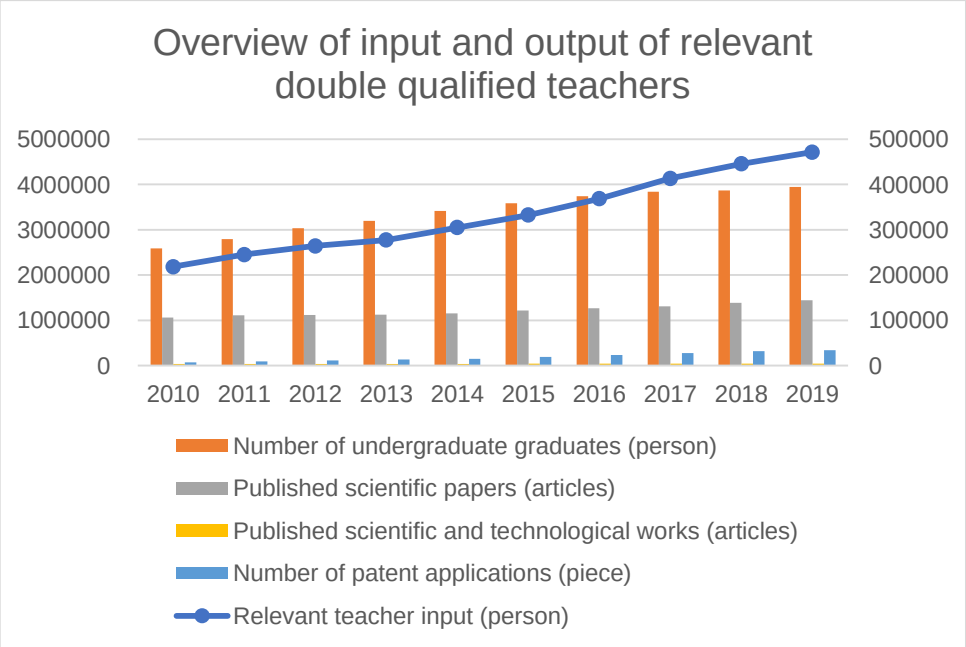

Fig 1: overview of input and output of relevant double qualified teachers

On the whole, the trend of output growth is similar to that of input growth, after 2017, double qualified teachers have a faster growth trend, and scientific research achievements still maintain a relatively uniform

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growth. It can be seen that teachers are the main force of scientific research in China's universities. If the differences in the proportion of teachers' contribution to scientific research are ignored, it can be roughly inferred from the data that scientific research related to the integration of production and education is not a simple crowd strategy. In recent years, there has been a trend of diminishing marginal benefits. In terms of changes in the number of undergraduates graduating, there has been an obvious growth slowdown trend since 2016. Generally speaking, the scale of graduates should be positively related to the investment of teachers. However, in recent years, China's population growth has slowed down, and higher education no longer aims to expand the scale and popularize facilities. It can be seen that China will continue to invest in university scientific research and student training, but higher education has increasingly shifted from expanding the scale to tackling key problems in quality. Cultivating students should pay more attention to combining industrial development with industrial needs. Under this background, the vocational education at the undergraduate level is ushering in the opportunity of reform [7].

In terms of economic investment, this paper deals with the training funds per student, calculates the total investment amount in combination with the number of graduates, then combines the R & D investment funds for cooperation between enterprises and colleges and universities, and analyzes the change trend of the two compared with the operating income of Industrial Enterprises above national scale, as shown in Fig 2.

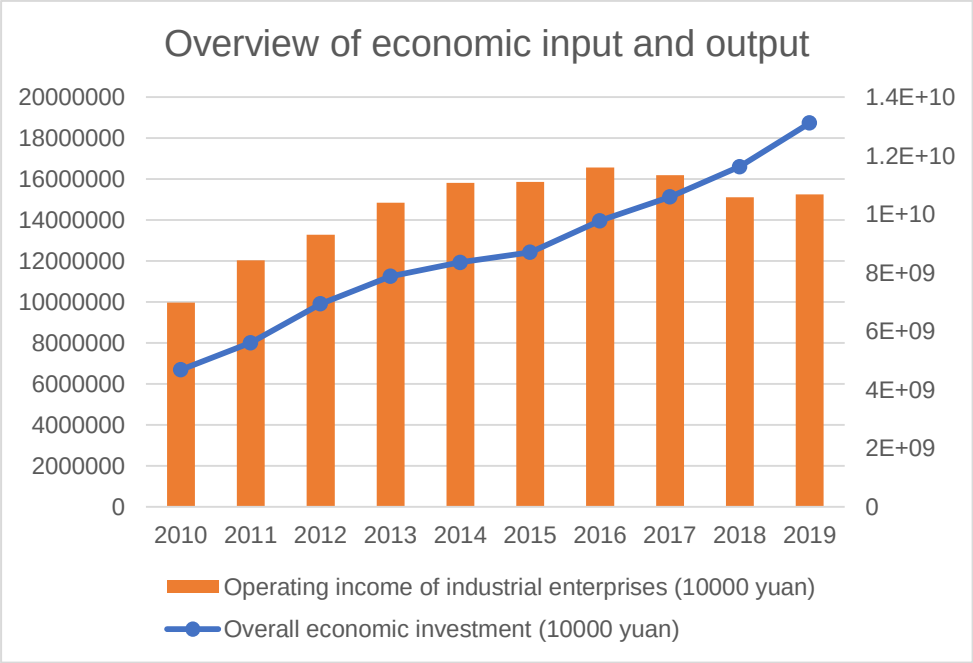

Fig 2: economic input and output of industry education integration of undergraduate Vocational Education

It can be seen that the economic investment related to the integration of industry and instruction has maintained a relatively smooth growth trend. Like human investment, China's investment in the integration

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of industry and instruction in undergraduate vocational education has maintained a strong growth trend, both from the perspective of enterprises and universities. In terms of output, since 2017, the operating income has dropped, which shows that the correlation between the enterprise's revenue and scientific research investment is weak. From another perspective, the revenue of Industrial Enterprises above designated size generally fell from 2017 to 2019. However, enterprises' investment in the integration of industry and instruction in universities maintained a strong growth. It can be seen that although the direct impact of industry education integration on the benefits of the enterprise itself is weak, or there is a long return cycle, both the enterprise level and the university level have strong confidence in the investment related to industry education integration.

3.2 DEA Efficiency Analysis of Economic Input

From the trend chart of comprehensive input and comprehensive output, it can be seen that the human and economic input related to the integration of industry and instruction in universities continues to grow. In terms of output, both the R & D scientific research achievements of universities and the operating income level used to measure the economic performance of enterprises are coincidentally slowing down or even falling in 2017. In this regard, the software DEAP 2.1 is used to analyze the data of 2010, 2017 and 2019. In the effectiveness analysis of DEA model, the input index of double qualified teachers is abandoned, Select the indicators related to capital input in the input indicators, and focus on the comprehensive efficiency of capital input and the output of industry education integration. The analysis results are shown in TABLE II.

TABLE II. Fund efficiency of industry education integration

Province	2010			2017			2019		
	Comprehensive efficiency	technical efficiency	Scale efficiency	Comprehensive efficiency	technical efficiency	Scale efficiency	Comprehensive efficiency	technical efficiency	Scale efficiency
Beijing	0.972	1	0.97	0.64	1	0.644	0.655	1	0.655
Tianjing	0.426	0.471	0.9	0.29	0.36	0.81	0.335	0.451	0.742
Hebei	0.848	0.853	0.99	0.94	0.98	0.953	1	1	1
Shanxi	0.584	1	0.58	1	1	1	0.816	0.837	0.976
Neimenggu	1	1	1	1	1	1	1	1	1
Liaoning	0.948	0.962	0.99	0.7	0.74	0.937	0.621	0.629	0.986
Jilin	0.486	0.59	0.82	0.87	0.94	0.928	0.771	0.847	0.91
HeilongJiang	0.498	0.595	0.84	0.48	0.53	0.909	0.512	0.565	0.907
Shanghai	0.784	0.985	0.8	0.52	0.82	0.633	0.494	0.96	0.515
Jiangsu	1	1	1	1	1	1	1	1	1
Zhejiang	1	1	1	0.66	0.82	0.805	0.71	0.88	0.807
Anhui	0.795	0.816	0.97	1	1	1	1	1	1
Fujian	1	1	1	0.91	1	0.908	0.836	0.908	0.92
Jiangxi	0.631	0.669	0.94	1	1	1	0.87	0.947	0.918

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Shandong	1	1	1	1	1	1	1	1	1
Henan	1	1	1	1	1	1	1	1	1
Hubei	0.915	1	0.92	0.85	0.94	0.898	0.759	0.891	0.852
Hunan	0.853	0.918	0.93	1	1	1	0.861	0.995	0.865
Guangdong	0.925	1	0.93	1	1	1	1	1	1
Guangxi	0.824	0.867	0.95	0.92	1	0.924	1	1	1
Hainan	1	1	1	1	1	1	1	1	1
Chongqing	1	1	1	0.48	0.56	0.849	0.572	0.642	0.891
Sichuan	0.701	0.708	0.99	0.79	0.8	0.984	0.818	0.822	0.996
Guizhou	0.649	1	0.65	0.71	0.72	0.982	0.61	0.725	0.841
Yunnan	0.579	0.629	0.92	1	1	1	1	1	1
Xizang	1	1	1	0.47	1	0.466	0.624	1	0.624
Shanxi	0.845	0.881	0.96	0.96	1	0.957	0.718	0.879	0.817
Gansu	0.396	0.413	0.96	0.59	0.65	0.919	0.478	0.556	0.86
Qinghai	1	1	1	0.67	1	0.665	0.718	0.982	0.732
Ningxia	1	1	1	0.96	1	0.956	0.444	0.454	0.979
Xinjiang	1	1	1	1	1	1	1	1	1
average value	0.828	0.883	0.94	0.82	0.9	0.907	0.781	0.87	0.896

Overall, the value of comprehensive efficiency in 2017 is close to that in 2010, and the capital efficiency in 2019 is lower than the previous two years. For the convenience of research, the results of scientific research are combined. From the analysis of the results, it can be seen that the capital efficiency is consistent with the trend of economic input and economic output analyzed in the previous analysis. From the perspective of provinces, the traditional major educational provinces Jiangsu and Shandong have always been at the forefront of production, Beijing and Hebei also have high comprehensive efficiency. However, the numerical values of the comprehensive efficiency of Qinghai, Ningxia, Xinjiang and other western provinces have changed greatly. The scale of early undergraduate education in these provinces is small, and the penetration rate of higher education is low. With the support of funds, they have achieved rapid results and obvious benefits, and soon form good results. With the passage of time, there are great fluctuations. It can be seen that after the outbreak stage of obvious results brought by economic investment, if you want to ensure the comprehensive efficiency of the integration of industry and instruction in universities, the management level of management subjects and the cooperation of policy-making also need to keep pace with each other.

The three-year pure technical efficiency in Table II is lower than the scale efficiency, which reflects that the management level of industry education integration in various regions of China is still relatively insufficient, and the scale efficiency of industry education integration is higher than the pure technical efficiency. It is pointed out that the management level and technical level are the main factors restricting the improvement of industry education integration efficiency in various regions. Taking the 2010 data in the table as a reference, it can be seen that the gap between scale efficiency and technical efficiency in 2017 and 2019 has narrowed significantly, which reflects that universities are working hard to improve their own management level. It should be noted that the gap between technical efficiency and scale

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efficiency in the northwestern provinces is large, and the fluctuation is particularly obvious, which highlights the relatively weak management level of these provinces.

3.3 Dynamic Analysis of Malmquist Index

Through the analysis of fund effectiveness by DEA model, the fund use efficiency of relevant investment in industry education integration can be presented intuitively. In order to further study its dynamic change from the time dimension and analyze the causes of the change, this paper uses Malmquist index for further analysis, and the decomposition results of Malmquist productivity index calculated by DEAP 2.1 software are shown in TABLE III.

TABLE III. Malmquist index and decomposition of industry education integration

Year	technical efficiency	technical progress	pure technical efficiency	Scale efficiency	Total factor productivity
2010-2011	0.899	1.202	0.934	0.963	1.081
2011-2012	1.052	0.762	1.033	1.018	0.802
2012-2013	1.083	0.918	1.028	1.054	0.995
2013-2014	0.885	1.248	0.925	0.957	1.105
2014-2015	1.012	0.984	1.023	0.989	0.995
2015-2016	1.077	0.962	1.056	1.021	1.036
2016-2017	0.993	0.913	1.03	0.964	0.906
2017-2018	0.954	0.945	0.974	0.979	0.901
2018-2019	1.004	0.899	0.993	1.011	0.903
average value	0.993	0.971	0.998	0.995	0.965

In the ten years since 2010, the average change of Malmquist index of relevant industry education integration economic investment is 0.965, indicating that the fund utilization efficiency of industry education integration of undergraduate vocational education in China is low. In terms of time dimension, the Malmquist index fluctuated greatly in the first half of the decade, and remained stable in the second half. This is because in 2014, the decision of the State Council on accelerating the development of modern vocational education proposes to explore and develop higher vocational education at the undergraduate level. Corresponding to the high fund implementation efficiency in the table from 2013 to 2014, with the introduction of top-level policies, universities emphasize the cultivation of applied talents in undergraduate teaching and attach importance to cooperation with enterprises. The clarity of policies and training objectives is conducive to the transformation of work ideas and management preference investment of colleges and universities [8]. In May 2019, the Ministry of education made it clear that it would work with various departments to introduce more supporting policies with gold content, and strive to achieve practical results in improving the status and treatment of technical and skilled talents, stimulating the endogenous motivation of enterprises and social forces to participate in vocational education, and strengthening the guarantee of vocational education conditions. Corresponding to the latter half of Table III, the implementation efficiency of relevant funds of universities in all regions of the country tends to be

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stable. It can be seen that universities have increased investment in the implementation of work in this field. Although the management level is still not perfect, phased results have been achieved. With the promulgation of the revised draft of the Vocational Education Law of the people's Republic of China in December 2019, the concept of "higher vocational schools" is revised to "Vocational Colleges and universities" side by side with "ordinary colleges and universities". Undergraduate vocational education has a clearer development direction for colleges and universities. This draft is about how to carry out relevant integration of industry and education, it has basic guiding significance [9].

From the perspective of spatial dimension, the decomposition of Malmquist index of 31 provinces (cities / autonomous regions) in China is shown in TABLE IV.

TABLE IV. Malmquist index decomposition table of production education fusion data in various regions

Province	technical efficiency	technical progress	pure technical efficiency	Scale efficiency	Total factor productivity
Beijing	0.957	0.977	1.000	0.957	0.935
Tianjing	0.974	1.012	0.995	0.978	0.985
Hebei	1.018	0.952	1.018	1.001	0.969
Shanxi	1.038	1.003	0.980	1.059	1.041
Neimenggu	1.000	0.991	1.000	1.000	0.991
Liaoning	0.954	0.976	0.954	1.000	0.931
Jilin	1.053	0.984	1.041	1.011	1.036
HeilongJiang	1.003	1.010	0.994	1.009	1.013
Shanghai	0.950	1.011	0.997	0.953	0.961
Jiangsu	1.000	1.016	1.000	1.000	1.016
Zhejiang	0.963	1.066	0.986	0.976	1.027
Anhui	1.026	1.036	1.023	1.003	1.063
Fujian	0.980	0.983	0.989	0.991	0.964
Jiangxi	1.036	0.983	1.039	0.997	1.018
Shandong	1.000	0.980	1.000	1.000	0.980
Henan	1.000	0.963	1.000	1.000	0.963
Hubei	0.979	0.956	0.987	0.992	0.936
Hunan	1.001	0.970	1.009	0.992	0.971
Guangdong	1.009	0.945	1.000	1.009	0.953
Guangxi	1.022	1.061	1.016	1.006	1.084
Hainan	1.000	0.961	1.000	1.000	0.961
Chongqing	0.940	0.955	0.952	0.987	0.898
Sichuan	1.017	0.965	1.017	1.001	0.982
Guizhou	0.993	0.983	0.965	1.029	0.976
Yunnan	1.063	0.998	1.053	1.009	1.060
Xizang	0.949	0.733	1.000	0.949	0.696

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Shanxi	0.982	1.021	1.000	0.982	1.003
Gansu	1.021	0.988	1.034	0.988	1.009
Qinghai	0.964	0.873	0.998	0.966	0.841
Ningxia	0.914	0.874	0.916	0.998	0.798
Xinjiang	1.000	0.951	1.000	1.000	0.951
average value	0.993	0.971	0.998	0.995	0.965

From 2010 to 2019, there are 11 provinces where the productivity index of the integration of industry and instruction in all regions of my country exceeds 1, accounting for only 35 percent, which means that the productivity of industry and instruction integration of universities in most regions in vocational education is still weak, and there is still much room for growth. In terms of growth factors, Tibet, Qinghai and Ningxia rely more on the improvement of technological progress, while other regions are more balanced and show a good momentum. As shown in Fig 3.

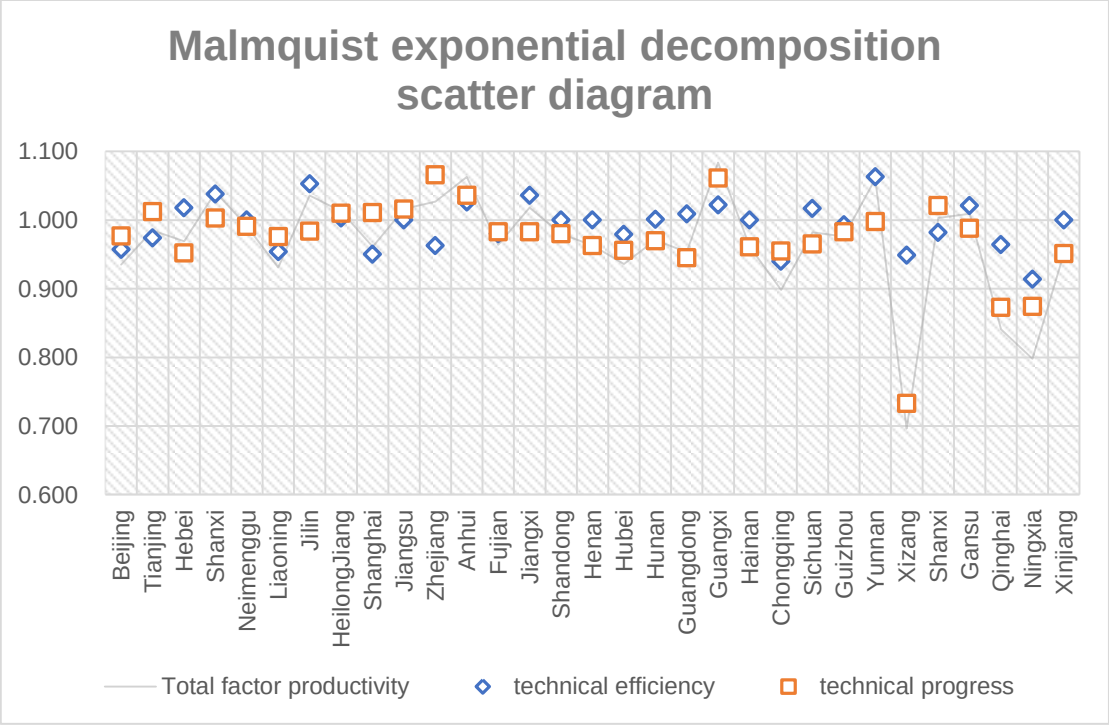

Fig 3: malmquist exponential decomposition scatter diagram

For Tibet, Qinghai and Ningxia, the main factor affecting the rise of the total factor productivity index is the platform construction level of the combination of industry and instruction. These universities lack the professional ability to drive related industries with scientific research. In the future, in the process of promoting the construction of undergraduate vocational education in these regions, talent introduction and technical support should be put in the first place. State owned enterprises, governments and other scientific research institutions should increase point-to-point and centralized experience transmission and technical force support to these areas.

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IV. SUMMARY

Through the empirical research on the integration of industry and instruction of universities in 31 provinces (cities/autonomous regions) in China from 2010 to 2019, the following conclusions can be drawn: Generally speaking, universities, governments and enterprises are optimistic about undergraduate vocational education. The state has gradually strengthened the construction of policies and resources. The investment in platform cooperation between enterprises and universities has increased strongly. Universities have made positive adjustments in terms of school transformation, professional talent training and teachers. In terms of economic input-output efficiency, based on the effectiveness analysis of DEA model, the selected data analysis results of 2010, 2017 and 2019 do not reach DEA effectiveness. There are also differences in the capital efficiency of the combination of industry and instruction among universities in different regions. There is still much room for improvement in the application of university capital efficiency. The government should have a reasonable incentive mechanism to stimulate teachers' enthusiasm, and strengthen its linkage and influence in the application research of enterprise production and education platform. Based on the dynamic analysis of Malmquist index, it can be seen that since 2010-2019, the average value of production and education integration productivity index in various regions has been 0.965, and Malmquist index has evolved from a large fluctuation state to a gradual stabilization over time, The integration of industry and instruction of undergraduate vocational education in various regions of China has achieved preliminary results. In terms of spatial dimension, from the analysis results of Malmquist index, some provinces rely too much on technological progress. Local economy and industry have a natural demand for vocational education, and undergraduate vocational education should also be based on relevant industries. Many local universities in China originated from the merger of multiple junior colleges in the early stage, and gradually developed into undergraduate universities through resource integration. Therefore, local universities have experienced several rounds of professional elimination and innovation in the process of their own development. From this point of view, China's universities are not afraid of reform, and even have rich reform experience. Nowadays, in addition to carrying out professional teaching with regional characteristics, the professional practicality of student training should also be emphasized, and the training process should also be introduced by other effective resources from enterprises or society, so as to maintain the cutting-edge of teaching. At the national policy level, in view of the dual characteristics of vocational general education and undergraduate level, more guiding implementation methods should be introduced to ensure that universities have clear themes and concentrated resources in the process of vocational education. At the level of universities, relevant scientific research funds invested by enterprises are used to fully integrate the demands of enterprises for talents and carry out practical teaching.

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