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Empirical Study on Key Influencing Factors of Energy Efficiency of Scientific and Technological Achievement Transformation in Higher Vocational Colleges and Universities Based on Big Data Analysis

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ABSTRACT

Promoting the output and transformation of scientific and technological achievements of higher vocational colleges and universities is not only the topic of promoting the high-quality development of education in higher vocational colleges and universities, but also the way to deeply implement the innovation-driven development strategy. Taking higher vocational colleges and universities in four municipalities directly under the central government as research samples, this study first utilizes the DEA model to measure the transformation efficiency of scientific and technological achievements of higher vocational colleges and universities in four municipalities directly under the central government in the period of 2014-2023, and combines with the literature analysis method to dig out the key influencing factors of their transformation energy efficiency. Then, the fuzzy set qualitative comparative analysis method (fsQCA) is used to carry out empirical research on the transformation efficiency due to inputs and outputs of scientific and technological achievements of the studied higher education institutions and the interactions between their influencing factors, so as to analyze the grouping path of the improvement of the energy efficiency of the transformation of scientific and technological achievements of the higher vocational colleges and universities. In the analysis of the results of measuring the efficiency of the transformation stage of scientific and technological achievements, the efficiency of the transformation stage of scientific and technological achievements of local higher vocational colleges and universities in D city is generally at a high level, with an average value of 0.427. Meanwhile, regional development factors (consistency 0.9081>0.9) and policy factors (consistency 0.9322>0.9) are the necessary conditions for the efficient transformation of scientific and technological achievements of higher vocational colleges and universities, and they are the key influences to improve the energy efficiency of scientific and technological achievements transformation.

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1. Introduction

As a national strategic scientific and technological force and an important part of the innovation system, colleges and universities are both an important supplier of scientific and technological achievements and an important force for the transformation of scientific and technological achievements. Higher vocational colleges and universities are oriented to enterprises to cultivate technical, application-oriented and service-oriented talents, and there is a big gap between them and undergraduate colleges and universities in both basic research and original innovation ability [1-3]. However, under the promotion of innovation-driven development strategy, the scientific and technological output of higher vocational colleges and universities has also gradually increased [4].

Higher vocational colleges and universities are an important place for scientific research and scientific and technological innovation, and a large number of scientific and technological achievements are born in various higher vocational colleges and universities every year [5-6]. However, only a small part of these scientific and technological achievements have been transformed, and how to realize the transformation of scientific and technological achievements is a problem that higher vocational colleges and universities need to further think about [7-8].

Enterprises focus on the transformation of innovations in technology to productivity or products, and higher education institutions focus on the transformation of innovations in knowledge and teaching methods to talent training [9]. From the end of the innovation chain, both focus on the level of knowledge release. Higher vocational colleges and universities to teach and educate people for the purpose of cultivating talents to promote the enhancement of social productivity, is to focus on the social benefits of talent training “production” activities [10-11]. While the output of science and technology needs talents with innovative consciousness and ability, the transformation of scientific and technological achievements needs talents with innovative and entrepreneurial ability even more. Therefore, higher vocational colleges and universities should not only realize the economic benefits of the transformation of scientific and technological achievements, but also pay more attention to its social benefits [12-13].

At the same time, the relevant policies of the state pointed out that it is necessary to fully support students' innovation and entrepreneurship, explore the establishment of innovation and entrepreneurship-oriented talent training mechanism, improve the synergistic model of combining industry, academia and research, encourage universities to authorize the use of scientific and technological achievements to students through gratuitous licensing of patents, and guide the students to participate in the transfer and transformation of scientific and technological achievements [14-15]. The Ministry of Education also puts forward the suggestion that we should promote the integration of science and education, and the collaboration of industry and education to cultivate high-quality innovative talents. This means that for higher vocational colleges and universities, focusing on the transformation of scientific and technological achievements into teaching resources and enhancing the cultivation of innovative and entrepreneurial capabilities of talents is an important way to promote the transformation of scientific and technological achievements in higher vocational colleges and universities [16-17].

Based on the DEA model and fsQCA method, this paper proposes a method for measuring and analyzing the influencing factors of the energy efficiency of the transformation of scientific and technological achievements in higher vocational colleges and universities. Higher vocational colleges and universities in 4 municipalities directly under the central government are selected as the research object, and the super-efficiency DEA model is used to measure the efficiency of transformation of scientific and technological achievements of higher vocational colleges and universities in 4 municipalities directly under the central government from 2014 to 2023. Then, literature analysis is used to explore the influencing factors of scientific and technological achievements transformation efficiency of higher vocational colleges and universities in 4 municipalities directly under the central government. Again, the empirical study was carried out, taking the six main influencing factors as conditional variables and the energy efficiency of transformation of scientific and technological achievements of higher vocational colleges and universities as outcome variables, using the fuzzy set qualitative comparative analysis method to calibrate and analyze the relevant data of higher vocational colleges and universities in the four municipalities directly under the central government, and finally summarizing the group path of the energy efficiency of transformation of scientific and technological achievements of higher vocational colleges and universities.

2. Method

2.1. Measurement of Energy Efficiency of Transformation of Scientific and Technological Achievements in Higher Education Institutions

2.1.1. DEA model. In this paper, we mainly use the input-oriented constant returns to scale (CCR) and variable returns to scale (BBC) based models in the DEA approach.

1) DEA-CCR model. Assuming that there is n decision-making unit DMU, each DMU has m inputs and q outputs, let $x_i(i=1,2,\cdots m)$ denote the inputs in each DMU, and $v_i(i=1,2,\cdots m)$ denote the weight coefficients of the input elements. Let $y_r(i=1,2,\cdots q)$ denote the outputs in each DMU and $u_r(i=1,2,\cdots q)$ denote the weight coefficients of the output elements [18]. Then, when evaluating the efficiency of the kth DMU, its efficiency is expressed as:

$$h_k=\frac{u_1y_{1k}+u_2y_{2k}+\cdots+u_my_{mk}}{v_1x_{1k}+v_2x_{2k}+\cdots+v_mx_{mk}}=\frac{\sum_{r=1}^{q}u_ry_{rk}}{\left(\sum_{i=1}^{m}v_ix_{ik}\right)},k=1,2,\cdots n \tag{1}$$

By noting the efficiency value of all DMUs according to the above weights as $\theta_j(i=1,2,\cdots n)$ and qualifying $0\le\theta_j\le1$, the CCR model can be expressed as:

$$s.t.\begin{cases}\max h_k=\dfrac{\sum_{r=1}^{q}u_ry_{rk}}{\left(\sum_{i=1}^{m}v_ix_{ik}\right)}\\ \dfrac{\sum_{r=1}^{q}u_ry_{rk}}{\left(\sum_{i=1}^{m}v_ix_{ik}\right)}\le1\\ u\ge0,v\ge0\\ i=1,2,\cdots m;r=i=1,2,\cdots q;j=1,2,\cdots n\end{cases} \tag{2}$$

After an equivalent linear programming, dyadic programming variation, the model can be equivalently expressed as:

$$s.t.\begin{cases} \min\theta \\ \sum_{j=1}^{n}\lambda_j x_{ij} \le \theta x_{ik} \\ \sum_{j=1}^{n}\lambda_j y_{nj} \ge y_{rk} \\ \lambda_j \ge 0 \\ i=1,2,\cdots m; r=i=1,2,\cdots q; j=1,2,\cdots n \end{cases} \tag{3}$$

If the optimal solution of linear programming $\theta = 1$, then DMU_k is said to be weakly DEA efficient. If $v^* > 0$, $u^* > 0$, and $\theta=1$ exist, then DMU_k is said to be DEA valid, i.e., the input-output ratio can be optimized. If $\theta<1$, then DMU_k is DEA invalid.

2) DEA-BCC model. The BBC model is based on the CCR model with the introduction of constraint $\sum_{j=1}^{n}\lambda_j = 1$, and its pairwise planning equation can be expressed as:

$$s.t.\begin{cases} \min\theta \\ \sum_{j=1}^{n}\lambda_j x_{ij} \le \theta x_{ik} \\ \sum_{j=1}^{n}\lambda_j y_{rj} \ge y_{rk} \\ \sum_{j=1}^{n}\lambda_j = 1 \\ \lambda_j \ge 0 \\ i=1,2,\cdots m; r=i=1,2,\cdots q; j=1,2,\cdots n \end{cases} \tag{4}$$

If the optimal solution of linear programming $\theta = 1$, then DMU_k is said to be weakly DEA efficient. If $v^* > 0$, $u^* > 0$, and $\theta = 1$ exist, then DMU_k is said to be DEA valid, i.e., the input-output ratio can be optimized. If $\theta<1$, then DMU_k is DEA invalid.

The CCR model calculates the result as Technical Efficiency (TE), the BCC model calculates the result as Pure Technical Efficiency (PTE), and Scale Efficiency (SE) is the ratio of Technical Efficiency/Pure Technical Efficiency, i.e.:

$$SE = TE / PTE \tag{5}$$

2.1.2.Malmquist exponential modeling. Since the level of technology changes over time, a comparative analysis of efficiency values over time cannot simply be measured directly using traditional DEA methods. Total factor productivity (TFP), on the other hand, refers to the additional efficiency achieved with given inputs, i.e., it is expressed as the portion of output growth that cannot be explained by the growth of factor inputs, and thus total factor productivity can be measured to compare the changes in efficiency of the production system over time. However, DEA, as a nonparametric estimation method, cannot calculate TFP, but it can calculate the TFP index. Combining the Malmquist index with the DEA method results in the Malmquist total factor productivity index (MI) model, and the Malmquist index is decomposed into two aspects of change: first, the change in technical efficiency (EC). The second is the movement of the production frontier surface, i.e., the change of production technology (TC), and the change of technical efficiency can be decomposed into the change of pure technical efficiency (PEC) and scale efficiency (SEC). By decomposing the TFP index, it is helpful for us to clearly understand the relationship between the various efficiency changes, so that we can look for the main root causes of the efficiency changes [19].

The basic idea of the Malmquist exponential model is to use the ratio of distance functions to measure efficiency changes. Assume that the inputs and outputs of DMU_k in period t are x_t and y_t, respectively, and that the inputs and outputs of $t+1$ are x_{t+1} and y_{t+1}. With constant returns to scale, denote by $D_t(x_t, y_t)$ the distance function of (x_t, y_t) in period t, and by $D_{t+1}(x_t, y_t)$ the distance function of (x_t, y_t) in period $t+1$. Denote by $D_t(x_{t+1}, y_{t+1})$ the distance function for (x_{t+1}, y_{t+1}) in period t, and by $D_{t+1}(x_{t+1}, y_{t+1})$ the distance function for (x_{t+1}, y_{t+1}) in period $t+1$.

Then the Malmquist indices based on periods t and $t+1$ can be expressed as respectively:

$$M_t = \frac{D_t(x_{t+1}, y_{t+1})}{D_t(x_t, y_t)} \tag{6}$$

$$M_{t+1} = \frac{D_{t+1}(x_{t+1}, y_{t+1})}{D_{t+1}(x_t, y_t)} \tag{7}$$

The formula for the Malmquist Total Factor Productivity Index with constant returns to scale in periods t through $t+1$ can be expressed as:

$$\begin{aligned} M_{(x_t, y_t, x_{t+1}, y_{t+1})} &= (M_t \times M_{t+1})^{\frac{1}{2}} \\ &= \left(\frac{D_t(x_{t+1}, y_{t+1})}{D_t(x_t, y_t)} \times \frac{D_{t+1}(x_{t+1}, y_{t+1})}{D_{t+1}(x_t, y_t)} \right)^{\frac{1}{2}} \\ &= \frac{D_{t+1}(x_{t+1}, y_{t+1})}{D_t(x_t, y_t)} \times \left(\frac{D_t(x_{t+1}, y_{t+1})}{D_{t+1}(x_{t+1}, y_{t+1})} \times \frac{D_t(x_t, y_t)}{D_{t+1}(x_t, y_t)} \right) \\ &= EC \times TC \end{aligned} \tag{8}$$

From Eq:

$$M_{(x_1, y_1, x_{t+1}, y_{y+1})} = PEC \times SEC \times TC \tag{9}$$

If $M_0 > 1$, it means that TFP is increasing from period t to period $t+1$. If $M_0 = 1$, then it means that TFP is constant. If $M_0 < 1$, it means that TFP is decreasing.

By calculating the Malmquist index and its decomposition, we are able to achieve a dynamic assessment of the efficiency of the production system, and thus analyze and obtain its trend.

2.2. Key influencing factor analysis based on fsQCA

2.2.1. Fuzzy set qualitative comparative analysis (fsQCA) approach. The core idea of Qualitative Comparative Analysis (QCA) is to fully compare and analyze cases through Boolean logic [20]. Ragin, from a holistic perspective, synthesizes the respective advantages of qualitative and quantitative analysis methods, and explores the combinations of different conditional factors corresponding to a particular outcome through the comparison and study of a large number of real-life cases, i.e., Qualitative Comparative Analysis (QCA). When using the qualitative comparative analysis method, it is necessary to analyze the entire social phenomenon from a group mindset based on the overall perspective of the case occurrence, and not to unilaterally seek to solve the resulting outcome from a single variable. The advantages and disadvantages of using the QCA method are mainly reflected in the following two points:

For one thing, qualitative comparative analysis (QCA) has the combined advantages of both qualitative and quantitative research methods. The traditional method of qualitative analysis is subject to the subjective influence of conditions, and scholars often even just summarize past cases by observation and analysis. However, the drawback of this approach is that it is easy to be interfered by personal subjective emotions when summarizing the laws of the case, and it is impossible to refine the influencing factors of the research conclusions internally, and it is even more difficult to deal with them by statistical methods. While traditional quantitative research can explain the causal links between social phenomena through quantitative means, and focuses more on the linear relationship between the variables, with objective and precise conclusions, the whole research process is linear and stereotypical, and the events in life are not so linear. Secondly, when the conditional variables of daily case events constrain each other and jointly affect the results of a certain social phenomenon, it is impossible to distinguish which factor plays a dominant role, and it is also impossible to answer the question of what combination of these factors affects the results together. Just as the efficiency of the transformation of scientific and technological achievements in higher vocational colleges and universities is not determined by a single factor, but by the combined effect of inputs, outputs, and environmental factors resulting in a comprehensive result. Therefore, this paper adopts qualitative comparative analysis (QCA), a non-linear aggregated perspective to study the causal relationship between the case events, and analyzes the conditions and outcome variables in the efficiency and output values in a comprehensive way, which essentially introduces the thinking of qualitative comparative analysis into the case of transformation efficiency of scientific and technological achievements in higher vocational colleges and universities, and explores what kind of causal relationship there is between transformation efficiency of scientific and technological achievements in higher vocational colleges and their inputs in the early stage, outputs in the mid-stage, and transformation in the late stage. The essence is to explore the causal relationship between the transformation efficiency of scientific and technological achievements of higher vocational colleges and the input in the first stage, the output in the middle stage and the transformation in the later stage, and to study the combination of conditions of influencing factors of the transformation efficiency of scientific and technological achievements of higher vocational colleges and universities in Anhui Province, and to explore the path of improving the efficiency from a diversified point of view, so that the results can be more reliable.

Qualitative Comparative Analysis (QCA) methods are divided into three main types, which are clear set qualitative comparative analysis (csQCA), multi-valued set qualitative comparative analysis (mvQCA), and fuzzy set qualitative comparative analysis (fsQCA). Clear set qualitative comparative analysis (csQCA) is characterized by "0/1" for the "presence/absence" of second-order variables, but because it is too arbitrary, it is likely to result in a loss of data, which can lead to biased results. Multi-Valued Set Qualitative Comparative Analysis (mvQCA) is based on the clear set, which extends the obtained result variable "0/1" to "0, 1, 2 ......" and even more orders of magnitude, and is able to process and analyze multiple categories of data simultaneously. However, its shortcoming is that the method is only suitable for assigning values to discrete data, while the two qualitative comparative analysis methods, clear set and multi-valued set, are only applicable to a certain type, not applicable to the study of continuous type. In the face of data diversity, these two methods are obviously more limited. This paper adopts the fuzzy set qualitative comparative analysis method in QCA (fsQCA for short) to analyze the efficiency of the transformation of research achievements in higher vocational colleges and universities in a group manner, which can identify the correlation and asymmetry between different conditional variables more efficiently than the other two methods, and can make the experimental results reach a higher standard of consistency. Fuzzy sets can be represented by any number between 0 and 1 when assigning values to variables, and this method can be used to deal with continuous variable values, overcoming the problem of the disadvantages of most studies in data processing and reducing the loss of data information.

2.2.2. Operational steps. The fuzzy set qualitative comparative analysis method (fsQCA) is divided into the following six steps:

The first step is to select the target case and variables. Based on the research needs to select the appropriate target case, in which it should be noted that in fuzzy set qualitative comparative analysis (fsQCA), the selection of the case should maintain appropriate differences and a reasonable number. Through the analysis of the research problem, a set of outcome and condition variables that can have an impact on the research results can be obtained through screening, and these variables will be included in our research. On this basis, data collection on the content of the study is then completed. This process requires careful selection of appropriate variable indicators based on the basis and principles in order to measure the research results more accurately.

In the second step, the sample dataset is constructed and variable calibration is performed. In QCA, variable calibration refers to a process of assigning affiliation to a set of variables.There are two methods of variable calibration in QCA, which are categorized into direct calibration and indirect calibration. The former is based on the theoretical foundation, using logistic functions, and calibrated after obtaining three qualitative anchors, namely, full affiliation, intersection, and full non-affiliation, through statistical software calculations. The latter means that the researcher refers to the relevant theories and calibrates according to his/her own research needs.

The third step is the necessity analysis of single conditions. In all research cases, when the individual condition variables and outcome variables are identified and adjusted, which is the calibration anchor points mentioned in the previous step, then there is still a need to analyze each condition variable, which is the necessity analysis. This is because if a particular condition variable is necessarily present if the outcome variable is present or absent, then this condition variable will necessarily be present in all grouped path configurations, and therefore there is no need to analyze it specifically.

In the fourth step, the truth table is constructed. After the necessity analysis, the combination of the condition variable and the outcome variable, i.e., the truth table, is derived. For the analysis of group paths, the frequency and consistency of the results can then be adjusted by filtering out all unqualified combinations and excluding those with low reliability.

The fifth step is the analysis of the grouping pattern under the causal asymmetric perspective. After establishing the truth table, the operation is continued through the QCA software, and the results obtained generally show three degrees of conditional combinations, which can be categorized as simple solution, complex solution and intermediate solution. It is usually believed that the intermediate solution results are more effective than the first two methods, and the specific reasons are described in detail later.

Step 6, robustness test. When the conclusion is obtained through the QCA software run, the analysis process needs to be re-validated by further adjustments to the variables or assumptions, etc. If the conclusion of the study remains unchanged, it can be considered that the results of the experiment are persuasive and that the experiment is reasonable in terms of the assumptions and arrangements [21].

2.2.3. Necessity analysis of single conditional variables. A necessary condition is a condition that must exist for the outcome to occur. Before constructing a truth table, necessity analysis needs to be performed on the condition variables. When conducting fsQCA software to analyze necessity, it is mainly judged by consistency. The higher the consistency value, the greater the likelihood that the condition variable is a subset of the outcome variable. If the consistency value for a single variable exceeds 0.9, the condition variable is considered necessary for the outcome variable. The magnitude of coverage is a measure of the degree of case coverage and indicates how strongly the condition variable explains the outcome. The formulas for consistency and coverage are shown below.

$$Consistency\left(X_i \le Y_i\right) = \sum\left[\min\left(X_i, Y_i\right)\right] \Big/ \sum X_i \tag{10}$$

$$Coverage\left(X_i \le Y_i\right) = \sum\left[\min\left(X_i, Y_i\right)\right] \Big/ \sum Y_i \tag{11}$$

Where, X_i denotes the calibrated fuzzy value of the condition variable and Y_i denotes the calibrated fuzzy value of the outcome variable.

3. Results and discussion

3.1. Measurement analysis of the transformation of scientific and technological achievements in higher education institutions

3.1.1. Indicator selection and data sources:

1) Selection of indicators. Evaluation of transformation efficiency of scientific and technological achievements of higher vocational colleges and universities is a complex systematic project, and the prerequisite for evaluating the transformation efficiency of scientific and technological achievements of higher vocational colleges and universities is to construct an index system with scientific, rational, objective and feasible features. Therefore, in the process of evaluating the transformation efficiency of scientific and technological achievements of higher vocational colleges and universities, it is necessary to take into account not only its social, economic and technological characteristics, but also the current situation of development of scientific and technological achievements of higher vocational colleges and universities. In this paper, after comprehensively considering the main indicators of measuring the transformation of scientific and technological achievements of higher vocational colleges and universities in existing research, the following indicators are finally selected as the indicators for measuring the transformation efficiency of scientific and technological achievements of higher vocational colleges and universities in this paper, and the evaluation index system of scientific and technological achievements transformation efficiency of higher vocational colleges and universities is shown in Table 1. The output of scientific and technological achievements of higher vocational colleges and universities cannot be separated from the input of talents and funds, therefore, this paper selects the full-time personnel of research and development and the funds for research and development to indicate the input indexes of scientific and technological achievements in the output stage. For higher vocational colleges and universities, the number of patents granted is the most typical among all kinds of scientific and technological achievements, and it is the most direct academic value embodiment of higher vocational colleges and universities' scientific and technological achievements, and it is often used as an indicator to measure the level of scientific and technological innovation of higher vocational colleges and universities, which embodies the scientific and technological research level of higher vocational colleges and universities to a certain level. Therefore, this paper uses the number of patents authorized to indicate the output index of the output stage of scientific and technological achievements as well as the input index of the transformation stage of scientific and technological achievements. In the stage of transformation of scientific and technological achievements, scientific and technological achievements are mainly commercialized through the sale and transfer of patents of higher vocational colleges and universities to realize their economic value, therefore, this paper selects the actual income of the year when the patents are sold and the actual income of the year when the technology is transferred as the two indexes to measure the outputs of the stage of transformation of scientific and technological achievements of higher vocational colleges and universities.

Table 1. The index system of the conversion efficiency

Stage	Index Type	Index Name	Unit
R&D Input	The First Stage Of The Input Index	Research And Development Of The Full Time Personnel	Human Year
		Research And Development Funds	Kilo
Technological Output	The First Phase Of The Output (The Second Order	Patent Number	Term

	Of Input Indicators)		
Technological Transformation	Output Index For Second Order Segment	The Patent Sells The Actual Income	Kilo
		Technology Transfer The Actual Income	Kilo

2) Data sources. The data on S&T activities used in this chapter are all from the Compendium of S&T Statistics of Higher Education Institutions issued annually by the Department of Science and Technology of the Ministry of Education, and the data on the S&T activities of local higher vocational colleges and universities in the four municipalities directly under the central government (City A, City B, City C, and City D) are mainly selected for the analysis from 2014 to 2023, and at the same time, in order to be able to objectively analyze the impact of the S&T innovation policy on the efficiency of transformation of scientific and technological achievements of local higher vocational institutions. The scope selected in this paper is limited to the data of scientific and technological activities of local higher vocational colleges and universities.

3.1.2. Measurement of the efficiency of the transformation of scientific and technological achievements in local higher vocational colleges and universities. This paper measures the efficiency of transformation of scientific and technological achievements of higher vocational colleges and universities in four municipalities through a two-stage network DEA model, and also compares the transformation of scientific and technological achievements of local higher vocational colleges and universities in four municipalities.

1) Analysis of the transformation efficiency of scientific and technological achievements of local higher vocational colleges and universities in D city. In this paper, the two-stage network DEA model will be used to measure the efficiency of the transformation of scientific and technological achievements of local higher vocational colleges and universities in D city, and the results of the efficiency of the transformation of scientific and technological achievements of local higher vocational colleges and universities in D city are shown in Table 2. Within the period from 2014 to 2023, the average value of the output stage (E1) of scientific and technological achievements of local higher vocational colleges and universities in City D is 0.465, the average value of the efficiency measured at the stage of transformation of scientific and technological achievements of higher vocational colleges and universities (E2) is 0.427, and the average value of the overall efficiency of the transformation of scientific and technological achievements of local higher vocational colleges and universities in City D (E) is 0.152. It can be seen through the above data that the scientific and technological achievements of local higher vocational colleges and universities in City D The overall transformation efficiency is lower than the sub-stages, and the transformation stage of scientific and technological achievements and the output stage of scientific and technological achievements are even more inefficient in comparison, and there is a serious problem of uneven distribution of efficiency.

From the perspective of scientific and technological achievements output stage, the efficiency of City D in this stage shows an overall increasing state, while the efficiency in the scientific and technological achievements transformation stage shows a decreasing trend. Therefore, the overall efficiency of the transformation of scientific and technological achievements of higher vocational colleges and universities in City D is in a state of low efficiency. From 2014 to 2023, the minimum value is 0.046, and the maximum value is only 0.25, which indicates that the overall efficiency of the transformation of scientific and technological achievements of higher vocational colleges and universities in City D is very low, and many scientific and technological achievements are still in the state of "sleeping", and there is a lot of space for transformation and improvement.

Table 2. The result of the conversion efficiency of science and technology

Time	E	E1	E2
2014	0.14623	0.14623	1
2015	0.08783	0.13695	0.61807
2016	0.10912	0.19797	0.54595
2017	0.09122	0.27891	0.32744
2018	0.18528	0.56501	0.33856
2019	0.24643	0.5083	0.49696
2020	0.2387	0.6111	0.39567
2021	0.04641	0.57824	0.08649
2022	0.15699	0.62625	0.25027
2023	0.21247	1	0.21247
Mean	0.152068	0.464896	0.427188

2) Cross-sectional comparative analysis of the efficiency of transformation of scientific and technological achievements of local higher vocational colleges and universities. Through the two-stage network DEA model, this paper calculates the results of the overall efficiency, output efficiency and transformation efficiency of the transformation of scientific and technological achievements of local higher vocational colleges and universities in the four municipalities of A, B, C, D. The results of measuring the overall efficiency of transformation of scientific and technological achievements are shown in Table 3. The results show that the overall efficiency of transformation of scientific and technological achievements of higher vocational colleges and universities in municipalities directly under the central government since 2014 is not high, and the average efficiency is less than 0.01, indicating that the ability of local higher vocational colleges and universities in municipalities directly under the central government in the transformation of scientific and technological achievements to effectively utilize resources of scientific and technological achievements is still in need of improvement.The efficiency of cities A and B is relatively stable in the period of 2014-2023. The efficiency of city C is very low in the period of 2014-2022, and the transformation efficiency reached 0.327 in 2023, which is the highest efficiency among the four municipalities during the ten-year period. In addition, the highest overall average efficiency of transformation of scientific and technological achievements of higher education institutions between 2014 and 2023 is in city D, which has an average efficiency of 0.154285.

Table 3. The results of the overall efficiency of the technological results

E	A	B	C	D	Mean
2014	0.07227	0.11537	0.00703	0.14727	0.085485
2015	0.08649	0.02303	0.01384	0.08613	0.052373
2016	0.03051	0.00948	0.00934	0.10507	0.0386
2017	0.0212	0.05147	0.00302	0.09305	0.042185
2018	0.04417	0.0595	0.00466	0.19192	0.075063
2019	0.03045	0.02057	0.00363	0.25698	0.077908
2020	0.02416	0.02308	0.00968	0.24415	0.075268
2021	0.0213	0.04455	0.01186	0.04714	0.031213
2022	0.04201	0.02944	0.00964	0.16014	0.060308
2023	0.0356	0.06571	0.32687	0.211	0.159795
Mean	0.040816	0.044220	0.039957	0.154285	0.06982

The results of measuring the efficiency of the output stage of scientific and technological achievements are shown in Table 4. It can be seen that the efficiency of local higher vocational colleges and universities in city C in the output stage of scientific and technological achievements in 2023 is 1. The efficiency of local higher vocational colleges and universities in city A in the output stage of scientific and technological achievements is the lowest among the municipalities, which indicates that the local higher vocational colleges and universities in city A produce less scientific and technological achievements after a large amount of financial input and manpower input. average efficiency ranks second in the municipality and exceeds the average value of the municipality.The efficiency of local higher vocational colleges and universities in the output stage of scientific and technological achievements in City C shows a growing trend in general, indicating that the scientific and technological achievements output in this stage in City C are growing continuously.The efficiency of local higher vocational colleges and universities in the output stage of scientific and technological achievements in City D shows a growing trend, and the value of the efficiency stays above 0.5 from 2018 to 2023, with its average value ranks first and far exceeds the average value, indicating that the scientific and technological achievements output in this stage in City D are continuously increasing.

Table 4. The results of the efficiency of the output phase

E1	A	B	C	D	Mean
2014	0.12886	0.32627	0.13909	0.14591	0.1850325
2015	0.13913	0.42878	0.18651	0.13686	0.22282
2016	0.13798	0.35677	0.15024	0.19579	0.210195
2017	0.11537	0.28745	0.14249	0.28815	0.208365
2018	0.18423	0.27829	0.19031	0.56177	0.30365
2019	0.21591	0.26952	0.2868	0.5048	0.3192575
2020	0.19134	0.28282	0.32713	0.61334	0.3536575
2021	0.15764	0.27374	0.32353	0.57619	0.332775
2022	0.16961	0.22025	0.26024	0.62825	0.3195875
2023	0.26606	0.38267	0.32507	1	0.49345
Mean	0.170613	0.310656	0.233141	0.465106	0.294879

The results of measuring the efficiency of the transformation stage of scientific and technological achievements are shown in Table 5. According to the table, it can be seen that the efficiency value of local higher vocational colleges and universities in city C in the stage of transformation of scientific and technological achievements in 2023 is 1, and the efficiency value of local higher vocational colleges and universities in city D in 2014 in the stage of transformation of scientific and technological achievements is also 1. The efficiency value of the stage of transformation of scientific and technological achievements of local higher vocational colleges and universities in city A briefly appears to increase in three years of 2015, 2018, and 2022, and shows a decreasing trend on the whole.Local higher vocational colleges and universities in city B have a The efficiency value of the transformation stage of scientific and technological achievements is low, with an average value of only 0.146. The efficiency of the transformation stage of scientific and technological achievements of local higher vocational colleges and universities in City C has been at a low level for a long time, but in 2023, the phenomenon of high efficiency appeared, with the highest value of 1. The efficiency of the transformation stage of scientific and technological achievements of local higher vocational colleges and universities in City D is at a higher level in municipalities directly under the central government, with an average value of 0.427, which is ranked the first among the four municipalities directly under the central government.

Table 5. The calculation results of the efficiency of the transformation phase

E2	A	B	C	D	Mean
2014	0.55507	0.35168	0.04725	1	0.4885
2015	0.63169	0.05068	0.05303	0.62016	0.33889
2016	0.21516	0.03705	0.06199	0.54593	0.2150325
2017	0.17593	0.17456	0.04767	0.31892	0.17927
2018	0.23918	0.22754	0.02154	0.33849	0.2066875
2019	0.1485	0.06699	0.02292	0.49399	0.1831
2020	0.13737	0.09351	0.0281	0.40074	0.16493
2021	0.14856	0.15365	0.02557	0.08427	0.1030125
2022	0.26526	0.12761	0.05482	0.25072	0.1746025
2023	0.1503	0.17805	1	0.21365	0.3855
Mean	0.266702	0.146132	0.136289	0.426687	0.2439525

3.2. Key influencing factors for transforming energy efficiency

Taking the papers directly exploring the factors influencing the transformation of scientific and technological achievements in the institutions of higher vocational colleges and universities as the research object, the proposed factors influencing the transformation of scientific and technological achievements are extracted from the relevant literature and analyzed through the clustering method.

3.2.1. Extraction of impact factors. A total of 507 influencing factors were extracted from 155 papers, and according to the attributes of each factor and the role of each link in the process of transformation of scientific and technological achievements, they were divided into six dimensions, including internal management factors, scientific and technological achievements factors, external demand factors, regional development factors, policy factors, and comprehensive service factors for the transformation of achievements, etc., and 66 influencing factors were extracted through the collation, analysis, and grouping of similar factors in each dimension, and 66 influencing factors affecting the transformation of The main factors and numbers affecting the transformation of scientific and technological achievements are shown in Table 6.

Table 6. Main factors affecting the transformation of scientific and technological achievements

Classification	Factor
Internal management factor	1.Research management mechanism. 2. Technology and r&d capability. 3.Technical output capacity. 4.The transformation incentive mechanism of the results.5.Knowledge property management level.6.The investment of scientific and technological achievements.7.R&d funding. 8.Development personnel investment.9.Technological achievements to transform talent teams.10. The evaluation mechanism of scientific research work.11.Evaluation of scientific achievements.12.Development cycle of the results.13.Technical integration innovation ability.14.Ability to promote scientific and technological achievements.15.Technology transformation consciousness.16.The selection of scientific research topics matches the requirements.17.The evaluation of the title.18.Scientific and technical equipment conditions. 19.Match with the industrial chain.20.Market docking level.21.The ability of scientific research institutions to provide social services.22.Results translate into follow-up services.23.Scientific ethics.24.Cooperation on production and research.25.International exchange level
Scientific and technological achievements	26. The matching between the results and the needs. 27.The level of scientific and technological achievements.28.Technology maturity.29.Achievement transformation cycle.30.Technology versatility.31.technology advancement. 32.Regional nature of technology. 33.Technical reliability. 34.Technical practicality.35.Technical complexity.36.Technology and economy. 37.Technical feasibility.
External demand factor	38.Into the conversion ability of the young side.39.Into the sound of the young side. 40. Market skills to seek cold.41.Into the absorption of the young side to the Li magnetic mechanism.42.Into the absorption of the innovative consciousness.43.Information on the technical needs of the outcome recipients
Regional development factors	44. Level of regional development.45.Degree of regional financial development. 46.Economic environment.47.Regional industrial structure. 48, open to the outside world.49.Interregional development. Department.50.Regional industrial development.51.Social culture
Policy factors	52. Policy environmental impact. 53. Government guidance. 54. Legal and regulatory factors
Integrated service factor for results transformation	55.Science and technology intermediary services.56.Information communication

	mechanism.57.Scientific and technological achievements transformation platform built 58. Technical activity 59 Lidui Guang Kong spectrum 60.Staining Financing channels: 61.information credibility: 62, technology market development: 63, science and technology information service platform. 64. Comprehensive support for the transformation of results. 65.Pilot environment.66. Information mining and utilization

3.2.2. Analysis of major influencing factors. In the analysis of influencing factors, it is necessary to think about and analyze the relationship between factors, such as causal relationship, process relationship, environmental relationship, functional relationship, etc., and analyze and screen out the key factors that can best reflect the research theme. In this paper, through clustering analysis, we screened the most concerned indexes in the existing research, and based on the large-scale complex network analysis and visualization function of Node XL software, we measured the parameters such as linkage degree, intermediary centrality degree, proximity centrality degree, eigenvector centrality and Page Rank of individual factors affecting the transformation of scientific and technological achievements, and the correlation analysis of the factors affecting the transformation of scientific and technological achievements is shown in Figure 1. Through the measurement and comprehensive analysis of each factor, the key factors affecting the transformation of scientific and technological achievements are shown in Table 7.

Table 7. Key factors that affect the transformation of science and technology

Factor coding	Link degree	Intermediate center	Proximity center	Eigenvector center	PageRank
1	31	37.364	0.012	0.025	1.647
2	26	27.908	0.01	0.024	1.241
3	22	29.249	0.009	0.019	1.198
4	33	71.028	0.012	0.03	1.794
5	14	-2.361	0.007	0.015	0.776
6	31	68.352	0.01	0.027	1.731
7	29	169.063	0.013	0.028	1.857
8	14	13.832	0.009	0.014	0.945
9	39	148.765	0.013	0.031	2.057
10	28	19.439	0.008	0.017	1.52
11	2	0.000	0.009	-0.002	0.212
12	2	0.000	0.002	0.008	0.231
13	12	0.277	0.008	0.01	0.63
14	12	6.237	0.007	0.01	0.736
15	36	90.749	0.009	0.02	1.868
16	24	14.863	0.01	0.02	1.244
17	15	0.4108	0.013	0.018	0.713
18	12	6.306	0.008	0.009	0.581
19	5	0.653	0.008	0.004	0.314
20	4	0.821	0.008	0.005	0.411
21	9	16.035	0.007	0.009	0.756
22	11	2.169	0.013	0.011	0.576
23	2	0.000	0.012	0.007	0.506

24	32	13.491	0.009	0.027	1.433
25	2	0.959	0.009	-0.001	0.435
26	39	77.875	0.013	0.025	1.866
27	24	1.582	0.009	0.013	0.829
28	25	14.006	0.006	0.02	1.34
29	13	0.666	0.005	0.012	0.511
30	9	1.194	0.011	0.018	0.671
31	16	9.879	0.009	0.009	1.035
32	3	0.000	0.009	0.004	0.419
33	3	0.000	0.007	0.013	0.614
34	44	80.896	0.008	0.034	1.979
35	20	9.938	0.01	0.017	1.073
36	10	4.443	0.009	0.01	0.666
37	15	3.991	0.003	0.019	0.746
38	42	68.714	0.012	0.032	1.981
39	21	2.75	0.007	0.024	1.027
40	21	22.751	0.011	0.019	1.272
41	8	1.775	0.009	0.011	0.725
42	19	18.63	0.005	0.014	1.012
43	11	0.145	0.007	0.007	0.541
44	25	135.613	0.007	0.018	1.319
45	2	0.000	0.003	-0.001	0.35
46	2	0.000	0.004	0.008	0.48
47	2	0.000	0.006	0.003	0.37
48	2	0.000	0.01	0.005	0.516
49	2	0.000	0.008	0.009	0.464
50	8	2.563	0.01	0.009	0.734
51	2	0.000	0.006	0.006	0.367
52	51	215.852	0.013	0.028	2.527
53	21	1.044	0.004	0.018	1.021
54	18	3.071	0.01	0.017	0.895
55	40	80.683	0.01	0.032	2.08
56	43	107.442	0.009	0.04	2.177
57	20	12.281	0.01	0.015	0.993
58	9	4.782	0.005	-0.002	0.549
59	14	30.228	0.011	0.018	1.206
60	36	43.652	0.008	0.032	1.782
61	3	0.000	0.009	0.003	0.215
62	31	7.972	0.008	0.02	1.234
63	3	0.000	0.009	0.002	0.423
64	19	11.213	0.007	0.012	0.863
65	32	22.895	0.012	0.028	1.508
66	3	0.000	0.005	0.002	0.37

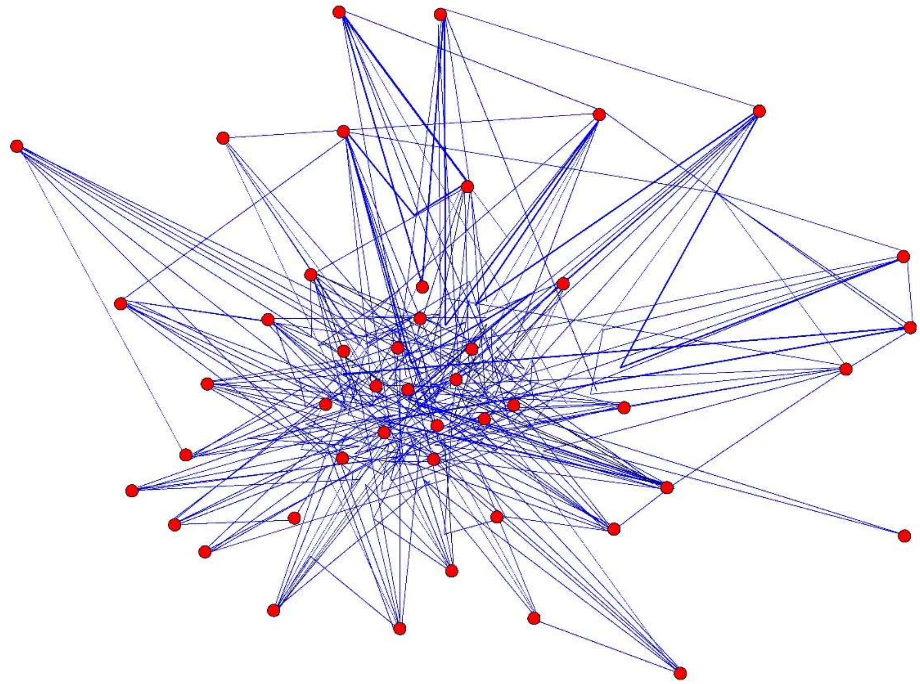

Fig. 1. Analysis of factors affecting the transformation factors

3.2.3. Analysis of the impact of major influencing factors. In order to further analyze the effects of the factors, the linkage, mediator centrality, proximity centrality, eigenvector centrality and PageRank index of each factor were normalized using z-score normalization method. The formulas are as follows:

$$r=\left[\left(D-D_{\mu}\right)/D_{\alpha}+\left(B-B_{\mu}\right)/B_{\alpha}+\left(C-C_{\mu}\right)/C_{\alpha}+\left(E-E_{\mu}\right)/E_{\alpha}+\left(P-P_{\mu}\right)/P_{\alpha}\right]/T \quad (12)$$

Where: r is the degree of influence of each factor. D is the linkage degree of each factor. D_{μ} is the linkage degree mean. D_{α} is the standard deviation of linkage degree. B is the mediated centrality degree of each factor. B_{μ} is the mediator centrality mean. B_{α} is the mediated centrality standard deviation. C is the proximity centrality of each factor. C_{μ} is the proximity centrality mean. C_{α} is the standard deviation of proximity centrality. E is the eigenvector centrality of each factor. E_{μ} is the eigenvector centrality mean. E_{α} is the proximity eigenvector centrality standard deviation. P is the PageRank value for each factor. P_{μ} is the PageRank mean. P_{α} is the PageRank standard deviation. Taking the influencing factors with positive influence degree as key influencing factors, the main factors affecting the transformation of scientific and technological achievements and the influence degree are shown in Table 8. The analysis shows that the transformation of scientific and technological achievements is greatly influenced by 29 indicators such as the influence of policy environment, information communication mechanism, etc. Among them, the influence of 12 indicators such as the influence of policy environment, information communication mechanism, talent team for transformation of scientific and technological achievements, investment in R&D funds and scientific and technological intermediary services has an influence degree of more than 1, which is more important for the transformation of scientific and technological achievements. In terms of internal management factors: including scientific research management system, scientific and technological research and development ability 11 influencing factors, indicating that a large part of the factors affecting the transformation of scientific and technological achievements come from within the organization, the research management system of higher education institutions and institutes, the goal orientation, personnel appraisal system, performance reward incentive system, and other intrinsic factors, which will affect the transformation of achievements by influencing the choice of scientific research direction, R & D investment, and the allocation of scientific and technological resources.

Table 8. The main factors affecting the transformation are the main factors and influence

Factor name	Influence degree	Factor name	Influence degree	Factor name	Influence degree
Policy environmental impact	2.83634	Investment in technological achievements	1.20134	Product promotion channel	0.27179
Information communication mechanism	1.95502	Investment channel	1.17594	Technical output capacity	0.25042
The scientific and technological achievements translate the talent team	1.77146	Research management mechanism	0.90349	The selection of scientific research is matched with the demand	0.23407
R&d funding	1.71269	Trial environment	0.76233	Technical market development	0.21566
Technology intermediary service	1.67312	Evaluation mechanism of scientific research work	0.75055	Government guidance	0.06726
Technical practicality	1.51653	Regional development level	0.74876	Technical advance	0.0592
Resultant absorption	1.50941	Productive research cooperation	0.66228	Technical complexity	0.04876
Technology transformation consciousness	1.43267	Scientific and technological ability	0.46616	Innovation consciousness of the result	0.0301
Results and requirements match	1.36539	Market technical requirements	0.42333	The results are absorbed by the will	0.01478
Resultant transformation incentive mechanism	1.30143	Technical maturity	0.37676	/	/

3.3. Grouping analysis of key influencing factors on energy efficiency of scientific and technological achievements in higher education institutions

3.3.1. Data calibration. In fsQCA, both the premise and outcome variables are considered as a set. Data calibration is the process of assigning affiliation scores to the set by setting the set affiliation between 0 and 1 and setting three critical values for the fully affiliated point, the crossover point and the fully unaffiliated point. In this paper, the direct calibration method was used and the data was validated using fs QCA 3.0 software. The 95% quantile value was set as the threshold for full affiliation, 5% was set as the threshold for incomplete affiliation, and 50% was set as the crossover point, and the calibration results of the outcome variables and condition variables are shown in Table 9.

Table 9. Result variable and conditional variable calibration results

	Variable	Full membership	Crossing point	Completely non-

				membership point
Result variable	Technological transformation	668263.64	79655	1185.3
Conditional variable	Internal management factor	15323144.65	3926122.65	541363.36
	Scientific and technological achievements	736155.25	186132.63	8865.62
	External demand factor	18633	8426	1596
	Regional development factors	42633	14231	3645
	Policy factors	3855263.63	1522361.62	382136.96
	Integrated service factor for results transformation	5988036.63	912366.36	48128.33

3.3.2. Findings:

1) Individual Conditional Necessity Analysis. When conducting fs QCA analysis, it is common to start by testing which precondition variables are necessary for the outcome variable, considering that the necessary condition is what causes the outcome to occur. In most cases, the presence of a necessary condition does not mean that the outcome must occur, but the absence of a necessary condition means that the outcome will not occur every time. When conducting fs QCA analyses, both consistency and coverage are often used to assess the strength of the causal relationship between combinations of premise variables and outcomes. In this case, consistency is used to measure the theoretical relevance of the relationship, and coverage indicates the proportion of cases under the relationship. The results of the analysis of the necessary conditions for the efficient transformation of scientific and technological achievements are shown in Table 10 ("~" means "not" in logical operations). Among them, the results of consistency of necessary conditions show that regional development factors (consistency 0.9081>0.9) and policy factors (consistency 0.9322>0.9) are necessary conditions for efficient transformation of scientific and technological achievements in higher vocational colleges and universities.

Table 10. The results of the analysis of the necessary conditions

Variable	Consistency	Coverage
Internal management factor	0.8884	0.8666
~ Internal management factor	0.4971	0.3794
Scientific and technological achievements	0.7222	0.6113
~ Scientific and technological achievements	0.5438	0.4851
External demand factor	0.8362	0.8308
~ External demand factor	0.4582	0.3615
Regional development factors	0.9081	0.8426
~ Regional development factors	0.458	0.3868
Policy factors	0.9322	0.7928
~ Policy factors	0.4452	0.3946
Integrated service factor for results transformation	0.4446	0.7652
~ Integrated service factor for results transformation	0.8653	0.6951

2) Conditional Grouping Sufficiency Analysis. Unlike individual conditional necessity analysis, group state analysis is used to reveal whether different groups of states consisting of multiple premise variables are sufficient conditions for the production of an outcome. In set-theoretic terms, it also explores whether the set of groupings of multiple premise variables is a subset of the set of outcomes. In fs QCA, the derived solutions are also evaluated based on two measures, consistency and coverage, with consistency ranging from 0 to 1, indicating the degree to which the combination of premise variables leads to the outcome. Once the researcher has incorporated the consistency combinations into the final solution, the second statistic, coverage, can be calculated. Coverage indicates how many cases of the outcome variable are represented by a particular causal complex condition in the data set, i.e., coverage reflects how much of the outcome is covered by each pathway and by the pathway as a whole. In general, conditional grouping sufficiency analysis can produce 3 different solutions: complex, intermediate, and parsimonious solutions. Complex solutions are produced when no logical remainders are used. When all logical remainders are used to seek parsimony, a parsimonious solution is produced. In general, complex solutions are difficult to interpret because they are overly complex, while parsimonious solutions blur the line between theory and case, and intermediate solutions use only simple counterfactuals. Therefore, the solution scheme of intermediate solutions is considered to be the best choice. In this paper, the intermediate solution is mainly solved, supplemented by the parsimonious solution. The results of the group analysis of efficient transformation of scientific and technological achievements are shown in Table 11 (solid circle indicates that the condition exists. Hollow circles with forks indicate that the condition does not exist. The empty space indicates that the condition has no effect. Large circles indicate core conditions and small circles indicate auxiliary conditions). The four groupings presented in Table 10 can be regarded as four combinations of sufficient conditions for the driving mechanism of transformation of scientific and technological achievements in higher vocational colleges and universities under the municipality, and the overall solution consistency is 0.9584, i.e., among the cases of transformation of scientific and technological achievements in higher vocational colleges and universities that satisfy the four types of conditional groupings, 95.84% of the transformation of scientific and technological achievements in higher vocational colleges and universities present a high rate of transformation. The coverage of the solution is 0.649, which means that the 4 types of conditional grouping states can explain 64.9% of the cases of efficient transformation of scientific and technological achievements in higher vocational colleges and

universities. Based on the conditional group state analysis, the synergistic relationship between internal management factors, scientific and technological achievements factors, external demand factors, regional development factors, policy factors and comprehensive service factors of achievements transformation in promoting the transformation of scientific and technological achievements of higher vocational colleges and universities is further identified, and the individual pathways are analyzed from the vertical level.

Table 11. The results of the efficient transformation of the technology

Condition	Solution			
	1	2	3a	3b
Internal management factor	●	●	●	●
Scientific and technological achievements	●	●		●
External demand factor	●	⊗	⊗	●
Regional development factors		●	●	●
Policy factors	●		●	●
Integrated service factor for results transformation	⊗	●	●	
Consistency	0.9605	0.9776	0.9706	0.9798
Original coverage	0.3927	0.5246	0.4229	0.4173
Unique coverage	0.0376	0.0653	0.0112	0.0171
Consistency of general solutions	0.9584			
The coverage of the general solution	0.649			

1) Path 1: Internal management factors*Science and technology achievements factors*External demand factors*Policy factors~Integrated services for transformation of achievements factors. This path to realize the efficient transformation of scientific and technological achievements of higher vocational colleges and universities shows that, in regions with backward level of regional development, if we can ensure that higher vocational colleges and universities have sufficient comprehensive services for the transformation of achievements and policy support, etc., and in the context of the close connection of industry-university-research cooperation network, we can still realize a high rate of transformation of scientific and technological achievements of higher vocational colleges and universities. This path requires internal management factors and external demand factors to play a central role, and scientific and technological achievements factors and policy factors to play a supporting role, which is named as internal resource-driven path in this paper. This path can explain about 45% of the cases of efficient transformation of scientific and technological achievements in higher vocational colleges and universities.

2) Path 2: Internal management factors*Science and technology achievement factors~External demand factors*Regional development factors*Results transformation integrated service factors. In provinces with sufficient human and financial resources of higher vocational colleges and universities, if funds are allocated to applied research and experimental development activities on a priority basis, supplemented by an excellent external economic environment and industry-academia cooperation network, it will help promote the efficient transformation of scientific and technological achievements

of higher vocational colleges and universities. Among them, internal management factors and regional development factors play a central role, and scientific and technological achievements factors, regional development factors and integrated service factors for transformation of achievements play a supporting role, which is named as network resource-driven path in this paper.
3) Path 3a: internal management factors ~ external demand factors * regional development factors * policy factors * integrated service factors for results transformation. In economically developed regions, higher vocational colleges and universities do not need to undertake a lot of applied research and experimental development work, as long as they provide sufficient technical support and good industry-academia cooperation network, higher vocational colleges and universities may realize efficient transformation of scientific and technological achievements. Among them, the policy factor and the integrated service factor of results transformation play an auxiliary role, and the variable of the number of people dispatched for cooperative research has no influence on the path. Therefore, this paper names it as internal-comprehensive enhancement type path.
4) Path 3b: Internal management factors*Scientific and technological achievements factors*External demand factors*Regional development factors*Policy factors. In the region with better regional economic development level, when the 2 conditions of internal management factors and regional development factors of higher vocational colleges and universities work at the same time, the efficient transformation of scientific and technological achievements of higher vocational colleges and universities can also be realized. Therefore it is named as external-overall enhancement type path.

4. Conclusion

This paper takes higher vocational colleges and universities in four municipalities directly under the central government as the research object, and uses data envelopment analysis (DEA) and network analysis to explore and analyze the energy efficiency of scientific and technological achievements transformation and the key influencing factors in higher vocational colleges and universities in four municipalities directly under the central government. Finally, the group path of transformation of scientific and technological achievements in higher vocational colleges and universities is classified and discussed in combination with the case study of actual colleges and universities. The research conclusions are specified as follows:

From the results of overall efficiency of transformation of scientific and technological achievements, efficiency of output stage of scientific and technological achievements, and efficiency of transformation stage of scientific and technological achievements of higher vocational colleges and universities in four municipalities, the value of the efficiency of transformation of scientific and technological achievements of local higher vocational colleges and universities in D city is the highest, and its E, E1, and E2 are at the high level among local higher vocational colleges and universities in the municipalities, and it is pulling away from the gap with the three cities of A, B, and C. Except for D, local higher vocational colleges and universities in city B perform better in the efficiency of scientific and technological achievements output stage, while local higher vocational colleges and universities in city A perform better in the efficiency of scientific and technological achievements transformation stage.

In the analysis of necessary conditions for efficient transformation of scientific and technological achievements, regional development factors (consistency 0.9081>0.9) and policy factors (consistency 0.9322>0.9) are the necessary conditions for efficient transformation of scientific and technological achievements in higher vocational colleges. At the same time, there exist four different paths that can support higher vocational colleges to accomplish the transformation of scientific and technological achievements better.

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