Collaborative Innovation Ability Cultivation of College Students by Improving Achievement Transformation Efficiency

https://doi.org/10.3991/ijet.v18i12.41089

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Abstract—With the increasingly urgent demand for innovative talents, college students should have strong collaborative innovation ability because they are the backbone of future sci-tech innovation in China. Existing methods can be used to measure and evaluate to some extent the collaborative innovation and achievement transformation efficiency of college students. However, many of the methods focus on data of a certain period and neglect dynamic analysis. Dynamic comparisons of different periods need to be made because innovation activities and achievement transformation may be influenced by time factors in practical situations. In addition, some methods only focus on the quantity index of achievement transformation, and neglect quality evaluation. Therefore, this paper aimed to study the collaborative innovation ability cultivation of college students by improving the achievement transformation efficiency. Three-stage data envelopment analysis (DEA)-Windows model was used to calculate the collaborative innovation and achievement transformation efficiency of college students. This paper elaborated in detail the calculation process of these three stages, namely, the first-stage DEA-Windows analysis, the second-stage panel stochastic frontier analysis (SFA), and the third-stage adjusted DEA-Windows analysis. Based on the research needs of collaborative innovation ability cultivation of college students by improving the achievement transformation efficiency, this paper constructed an evaluation index system using Fare-Primont index model and Pastor method, and focused on the sci-tech innovation achievement transformation factors, such as output results and ability improvement. Finally, this paper showed the analysis results by combining with examples, which verified the proposed method was effective.

Keywords—achievement transformation efficiency, innovation of college students, collaborative innovation ability

1 Introduction

With rapid technology development and accelerated global economic integration, higher education development is faced with unprecedented challenges and opportunities [1–7]. Collaborative innovation ability cultivation of college students by improving the achievement transformation efficiency has become an important topic in higher education reform [8–11]. On the one hand, with sci-tech progress and industrial structure adjustment, the demand for innovative talents is becoming increasingly urgent. As the future backbone of sci-tech innovation in China, college students should have strong collaborative innovation ability [12–17]. On the other hand, colleges and universities should shift the training mode from a single knowledge-based approach to a collaborative innovation approach in order to cope with increasingly fierce international competition [18–21]. In this context, it is necessary to study the collaborative innovation ability cultivation of college students by improving the achievement transformation efficiency. The research not only provides targeted methods and strategies for universities to cultivate innovation ability, improve the training quality, and promote the innovation ability development of college students, but also promotes the industry-university-research integration development, forms a good innovation ecology, and promotes the common progress of universities and the industry.

Cheng et al. [22] studied the impact of university-industry cooperation (UIC) policy concerning university knowledge innovation and achievement transformation based on the measurement of Chinese ministerial and provincial policies. The study examined the impact of UIC policy on research and development (R&D) investment from two sources (enterprise-university cooperation investment and government-university cooperation input) and transformation achievements at different stages of knowledge output and innovation chain, using the panel data of 30 universities from several provinces between 2000–2013. The results indicated that the UIC policy had a significant positive impact on both enterprise-university cooperation investment and government-university cooperation input. The relationship between UIC policy and knowledge output, and that between UIC policy and achievement transformation showed an inverted U-shape. For universities mainly engaged in enterprise-university cooperation activities, the UIC policy had a threshold effect on the interaction between government-university cooperation input and enterprise-university cooperation investment. In order to promote sci-tech achievement transformation of universities, deepen the implementation of unprecedented innovation driven development strategies, and solve the problems in the achievement transformation, Li et al. [23] analyzed the practical difficulties in the transformation, explored the implementation model of transformation carrier and three major functions of “sci-tech R&D, innovation entrepreneurship, and achievement transformation”, and proposed to construct a transformation carrier using computer technology, thus solving the disconnection between sci-tech achievements of universities and market demand and the controversy over the lack of R&D talents in enterprises. Zhou [24] proposed that sci-tech talents in universities and colleges, as the first source of the first productive force, had responsibility and ability to transform sci-tech achievements, thus improving the sci-tech achievement transformation in China. After long-term exploration, progress was made in the sci-tech law, with “promoting sci-tech achievement transformation” as the policy basis, which was of great significance. However, due to irrational and inconsistent policy structure, vague policy contents, and policy environment without systematic effects, the transformation of sci-tech achievements stagnated. Therefore, appropriate measures should be taken to improve the policy structure and contents, and matching policies should be implemented. Based on the panel data of 36 tourism universities between 2014–2017, Lei and Gao [25] divided the sci-tech achievement transformation into two stages of research creation and achievement transformation, measured the transformation efficiency using DEA-BCC model and DEA-Malmquist index model, and analyzed its changing trend. Relevant research results helped identify the problems of transformation efficiency, guided tourism universities to attach importance to sci-tech innovation, and provided some inspirations and suggestions for the universities to improve the transformation efficiency.

Although existing methods can be used to some extent measure and evaluate the collaborative innovation and achievement transformation efficiency of college students, they still have some shortcomings. Many of them focus on data of a certain period, while neglecting dynamic analysis. In practical situations, innovation activities and achievement transformation may be influenced by time factors, which leads to the need of dynamic comparisons of different time periods. In addition, some methods only focus on the quantity index of achievement transformation, while neglecting quality evaluation. Therefore, this paper aimed to study the collaborative innovation ability cultivation of college students by improving the achievement transformation efficiency. Chapter 2 calculated the collaborative innovation and achievement transformation efficiency of college students, using three-stage DEA-Windows model, and elaborated in detail the calculation process of these three stages, namely, the first-stage DEA-Windows analysis, the second-stage panel SFA, and the third-stage adjusted DEA-Windows analysis. Based on the research needs of collaborative innovation ability cultivation of college students by improving the achievement transformation efficiency, Chapter 3 constructed an evaluation index system using Fare-Primont index model and Pastor method, and focused on the sci-tech innovation achievement transformation factors, such as output results and ability improvement. Finally, this paper showed the analysis results by combining with examples, which verified that the proposed method was effective.

2 Measurement of collaborative innovation and achievement transformation efficiency of college students

Figure 1 shows the research model in this paper. The DEA-Windows analysis method is strongly dynamic, which reflects the changing trends and fluctuations in the collaborative innovation and achievement transformation efficiency of college students. The three-stage DEA-Windows model combines the three-stage DEA model with the DEA-Windows analysis method, and fully utilizes their advantages, thus improving the accuracy and reliability of calculation results. Data-driven approach avoids the impact of subjective factors on the evaluation results and improves the objectivity of calculation results. Therefore, this paper used the three-stage DEA-Windows model to calculate the collaborative innovation and achievement transformation efficiency of college students.

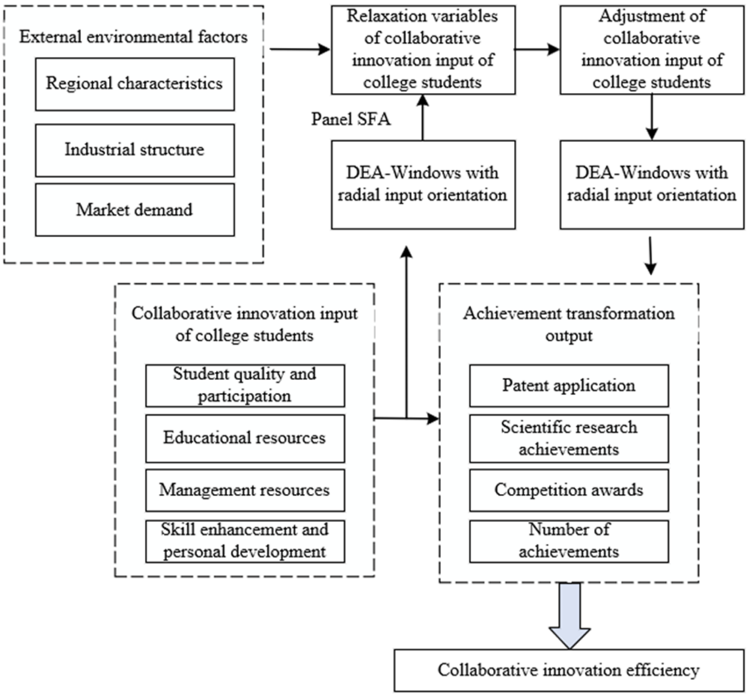

Fig. 1. Research model in this paper

The efficiency calculation was divided into three stages, namely, the first-stage DEA-Windows analysis, the second-stage panel SFA, and the third-stage adjusted DEA-Windows analysis. The processes of these three stages were as follows:

(1) The first-stage DEA-Windows analysis:

In the first stage, the DEA-Windows analysis method was used to preliminarily measure the collaborative innovation and achievement transformation efficiency of college students. Appropriate input and output indexes were first selected to measure the effectiveness. Then the width of sliding window was set to evaluate the efficiency under dynamic conditions. By calculating the efficiency values of various decision-making units (DMUs) (e.g. colleges, majors, etc.) at different time periods, this paper preliminarily understood the efficiency level and changes of the collaborative innovation and achievement transformation of college students. This paper measured the achievement transformation efficiency value from the point of collaborative innovation input of college students using the BCC model, with the window width set to 3. Then this paper output the data of collaborative innovation input and achievement transformation output, and calculated the dynamic DMU achievement transformation efficiency and the relaxation variables of collaborative innovation input variables.

Let i be the region, j be the number of collaborative innovation input indexes, s be the number of achievement transformation output indexes, a be the collaborative innovation input element, b be the achievement transformation output element, μ be the weight coefficient of the j-th collaborative innovation input index and the s-th achievement transformation output, r^{+} and r^{-} be the relaxation variables of collaborative innovation input and achievement transformation output of DMU, and ω be the effective DMU value. The following equation provided the BCC model expression for collaborative innovation input orientation:

$$\min \omega - \rho(o^{p} r^{-} + o^{p} r^{+})$$
$$s.t. \begin{cases} \sum_{i=1}^{m} \mu_i b_{is} - r^{-} = b_{0s} \\ \sum_{i=1}^{m} \mu_i a_{ij} + r^{-} = \omega a_{0j} \\ \sum_{i=1}^{m} \mu_i = 1, \mu_i \geq 0, r^{-} \geq 0, r^{+} \geq 0 \end{cases} \quad (1)$$

(2) The second-stage panel SFA:

The collaborative innovation and achievement transformation efficiency of college students was influenced by three factors, namely, internal management factors of universities, external environmental factors, and random interference factors. The efficiency was affected by several internal management factors, such as the management level, organizational structure, leadership, and decision-making ability of universities. An effective management system and a good organizational atmosphere stimulated students' innovation potential and improved the collaborative innovation and achievement transformation efficiency. The efficiency may also be influenced by external environment, such as regional characteristics, industrial structure, and market demand. A good external environment provided students with more practical opportunities, and promoted collaborative innovation and achievement transformation. In addition, the efficiency may also be influenced by random interference factors, such as unexpected events and technological breakthroughs, which may lead to efficiency fluctuations, but may not necessarily have a long-term impact on the efficiency level.

The relaxation variables of collaborative innovation input index of college students, measured during the DEA-Windows analysis stage, were divided into three parts using the panel SFA method, namely, internal management factors of universities, external environmental factors, and random interference factors. In order to ensure that the remaining efficiency values mainly reflected the redundancy caused by internal management factors, SFA was used to eliminate the impact of external environment and random interference factors on the collaborative innovation input index. Then this paper obtained more homogeneous adjusted DMUs, making it easier to compare and analyze the collaborative innovation efficiency of different DMUs.

Let R^{-}_{njp} be the relaxation variable of the n-th collaborative innovation input of DMU_j during the p-period, $g(C_{njp}; \gamma_{njp})$ be the impact of external environment on the relaxation variable, C_{njp} be the external environment, γ_{njp} be the corresponding external environment coefficient, $U_{njp}+\lambda_{njp}$ be the comprehensive error, U_{njp} be the random error, and λ_{njp} be the management inefficiency. This paper considered the measured relaxation variables as the explained variables, the external environmental factors as the explaining variables, and established the following panel SFA equation:

$$R^{-}_{mjt} = g\,(V_{njp}; \gamma_{njp}) + u_{njp} + \lambda_{njp};\ j = 1,2,\ldots,J;\ n = 1,2,\ldots,N \tag{2}$$

It was assumed that $n = 1, 2, ..., N$, and $j = 1, 2, \ldots, J$. Let a^*_{nj} be the adjusted collaborative innovation input index value, a_{nj} be the original collaborative innovation input index value, $\max\{z_j\beta_m\}-z_j\beta_m \max\{c_j\gamma_n\}-c_j\gamma_n$ be all DMUs placed in the same and worst external environment, and $\max a_j\ \{u_{nj}\}-u_{nj}$ be all DMUs placed in the same random interference. That is to say, DMUs with good external environment or high random interference increased the collaborative innovation input of college students. Based on the panel SFA regression results, the collaborative innovation input index value for each DMU was:

$$a^*_{nj} = a_{nj} + \left[\max\left\{c_j\gamma_n\right\} - c_j\gamma_n\right] + \left[\max a_j\left\{u_{nj}\right\} - u_{nj}\right] \tag{3}$$

Finally, this paper separated the random interference and internal management factors. Let ψ and Ψ be the density function and distribution function of standard normal distribution, then $\varepsilon^{2*} = \varepsilon^2_v\varepsilon^2_u/\varepsilon^2$, and $\mu = \varepsilon_u/\varepsilon_v$, $\rho_j = u_j+\lambda_j$. The following equation provided the expression of the random interference factors:

$$O\left[u_{nj} \mid u_{nj} + \lambda_{nj}\right] = R^{-}_{njp} - C_j\gamma_n - O\left[\lambda_{nj} \mid u_{nj} + \lambda_{nj}\right] \tag{4}$$

$$O\,(\lambda_j \mid \rho_j) = \frac{\mu\varepsilon}{1+\mu^c}\left[\frac{\psi(\rho_j\mu/\varepsilon)}{\Psi(\rho_j\mu/\varepsilon)} + \frac{\rho_j\mu}{\varepsilon}\right] \tag{5}$$

(3) The third-stage adjusted *DEA-Windows* analysis:

In the third stage, this paper substituted the new collaborative innovation input and original achievement transformation output data of each DMU once again into the DEA-Windows model, and adjusted the efficiency value of the first-stage DEA-Windows analysis, based on the adjustment coefficient obtained from the second-stage SFA. Specifically, the adjusted efficiency value was obtained by multiplying the original efficiency value of each DMU with the corresponding adjustment coefficient. These adjusted efficiency values better reflected the true efficiency level of collaborative innovation and achievement transformation, because they had eliminated the influence of external environmental factors and random interference factors.

3 Evaluation of collaborative innovation and achievement transformation efficiency of college students

Based on the research needs of collaborative innovation ability cultivation of college students by improving the achievement transformation efficiency, this paper used the Fare-Primont index model and Pastor method to construct an evaluation index system, and focused on sci-tech innovation achievement transformation factors, such as the output results and ability improvement.

Fare-Primont index model is a comprehensive productivity index model, which measures changes of productivity. This model can be used to evaluate the changes of collaborative innovation productivity in different stages, fields, colleges, and so on, thus understanding the improvement of innovation achievement transformation efficiency. Pastor method is an evaluation index system construction method based on DEA. Combined with the research needs of collaborative innovation ability cultivation of college students, an evaluation index system can be built by selecting appropriate input indexes (e.g., educational resources, policy support, etc.) and output indexes (e.g., output results of innovation achievement transformation, ability improvement of students, etc.).

In the evaluation index system, this paper needed to pay attention to the output results of the sci-tech innovation achievement transformation of college students, such as the number of patent applications, the amount of money in achievement transformation contracts, and the number of incubated enterprises, because these indexes helped understand the achievement transformation efficiency improvement and provided a basis for further optimizing collaborative innovation strategies. In addition, this paper needed to pay attention to the factors related to the ability improvement of college students in the evaluation index system, such as the number of students participating in innovation projects and the situation of winning competition awards, because these indexes reflected the cultivation effectiveness, helped identify key factors affecting ability improvement, and proposed corresponding improvement measures.

This paper constructed a comprehensive and reasonable evaluation index system using the above method processes, thus evaluating the achievement transformation efficiency improvement of collaborative innovation ability cultivation of college students. This helped universities better adjust innovation strategies, promoted the collaborative innovation ability cultivation of college students, and improved the achievement transformation efficiency.

In the case of multiple collaborative innovation inputs and achievement transformation outputs, this paper defined the collaborative innovation technology level of college students as the ratio of the total achievement transformation output to the total collaborative innovation input. Let $A_{io} = \{a_{1io}, \ldots, a_{Lio})$ and $B_{io} = \{b_{1io}, \ldots, b_{Jio})$ be the collaborative innovation input and achievement transformation output vectors of DMU_i in the t period, Bio be the total achievement transformation output, A_{io} be the total collaborative innovation input, and *B(.)* and *A(.)* be the non-negative and non-decreasing homogeneous linear functions, then the collaborative innovation technology level of college students of DMU_i was expressed as:

$$OGE = \frac{B_{io}}{A_{io}} \tag{6}$$

Let OGE_o^* be the maximum value that may be reached under technological level constraints during *o* period, which satisfied $OGE_p^* = \max B_{io}|A_{io}$. Let A_o^* and B_o^* be the total collaborative innovation input and the total achievement transformation output when technological level obtained the maximum value. According to the definition, the comprehensive transformation efficiency of college students in a certain university was defined as the ratio of the actual collaborative innovation technology level to the maximum technology level in the same period, and then there was:

$$P_{io} = \frac{OGE_{io}}{OGE_o^*} = \frac{B_{io} / A_{io}}{B_o^* / A_o^*} \tag{7}$$

Under the collaborative innovation input orientation condition of college students, the comprehensive achievement transformation efficiency *P* was decomposed into collaborative innovation technology efficiency IOP, collaborative innovation scale efficiency IRP, and residual mixed efficiency SNP. Let $\overline{A}_{io} = A_{io} \times C_I(a_{io}, b_{io}, o)^{-1}$ be the possible minimum total collaborative innovation input when the collaborative innovation input vector a_{io} output achievement transformation performance bio, $\widehat{B}_{io}$ and $\widehat{A}_{io}$ be the maximum total achievement transformation output and total collaborative innovation input achieved, IRP_{io} be the measurement of performance related to economies of scale corresponding to achievement transformation output, and SNP_{io} be the residual mixed efficiency representing the benefits brought by the optimized collaborative innovation achievement transformation output combination of college students, then there were corresponding formulas and relationships as follows:

$$P_{it} = \frac{OGE_{io}}{OGE_o^*} = IOG_{ip} \times IRP_{io} \times SNP_{io} \tag{8}$$

$$IOP_{io} = \frac{B_{io} / A_{io}}{B_{io} / \overline{A}_{io}} = \frac{\overline{A}_{io}}{A_{io}} = C_I(a_{io}, b_{io}, o)^{-1} \leq 1 \tag{9}$$

$$IOP_{io} = \frac{B_{io} / \overline{A}_{io}}{\widehat{B}_{io} / \widehat{A}_{io}} \leq 1 \tag{10}$$

$$SNP_{io} = \frac{\widehat{B}_{io} / \widehat{A}_{io}}{Tech_o} \leq 1 \tag{11}$$

While setting transformation efficiency evaluation indexes, this paper needed to consider the following detailed input and output indexes:

The input indexes included four aspects, namely, student factors, educational resource factors, management factors, and ability improvement factors. Specifically, first, student factors included student quality and engagement. The former referred to basic knowledge, innovation ability, teamwork ability, and learning motivation of students. The latter referred to the number of students participating in innovation projects, and their participation level. Second, educational resource factors included teacher resources, experimental facilities, and curriculum setting. Teacher resources referred to the number of teachers, their academic level and research experience. Experimental facilities included the number of laboratories, types and quantities of experimental equipment for collaborative innovation of students. Curriculum setting included the quantity and quality of innovative courses. Third, management factors consisted of two aspects, organizational coordination and policy support, including interdisciplinary cooperation, integration of teaching and research, support of governments and universities for innovation projects and incentive measures. Fourth, ability improvement factors included skill enhancement and personal development, i.e. the number of students participating in innovative projects, the situation of students receiving competition awards, employment quality and further study of students.

Output indexes included innovation output and achievement transformation output. The former included four aspects, namely, patent application, scientific research achievements, competition awards, and number of achievements. First, patent application included the number of patents applied and authorized, etc. Second, scientific research achievements included the number and quality of published papers. Third, competition awards included the number and level of awards in various technological innovation competitions. Fourth, number of achievements included the number of sci-tech achievement transformation contracts and contract amount, and the number of incubated enterprises.

In the actual evaluation process, the above indexes can be adjusted and supplemented according to specific situations of different universities. At the same time, the rationality of weight allocation should be paid attention in order to ensure that the status and role of each index in the evaluation system are fully reflected.

4 Experimental results and analysis

Combined with examples, this paper compared the collaborative innovation achievement transformation efficiency of college students at different stages. Figure 2 was used to analyze the transformation efficiency changes between the first and second stages. For the convenience of analysis, this paper calculated the changes of efficiency values for each university (the second-stage value minus the first-stage value). The following three conclusions were drawn based on the changes: first, the transformation efficiency values of eleven universities (Universities 1, 4, 5, 6, 8, 9, 11, 14, 15, 17, 27) increased in the second stage, with University 17 having the largest increase and reaching 0.24. Second, the transformation efficiency values of sixteen universities (Universities 2, 3, 7, 10, 12, 13, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26) decreased, with University 22 having the largest decrease and reaching –0.90. Third, the transformation efficiency values of some universities changed significantly in the second stage. For example, the values of Universities 18, 22, and 24 dropped to 0, while that of Universities 5 and 14 increased.

This paper further drew a static matrix diagram of transformation efficiency. According to Figure 3, universities are divided into four different types: universities with high knowledge innovation and achievement transformation efficiency, universities with low low knowledge innovation and achievement transformation efficiency, universities with high achievement transformation efficiency and low knowledge innovation efficiency, and universities with high knowledge innovation efficiency and low achievement transformation efficiency.

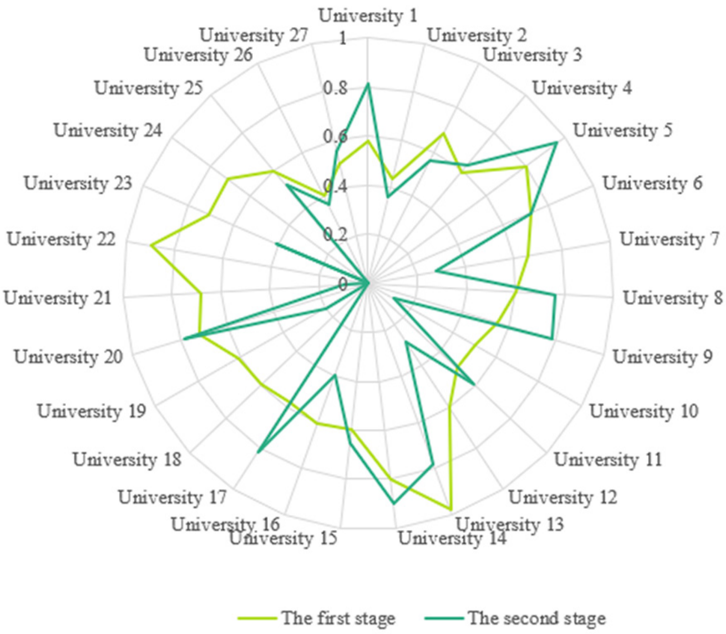

Fig. 2. Collaborative innovation achievement transformation efficiency comparison of college students at different stages

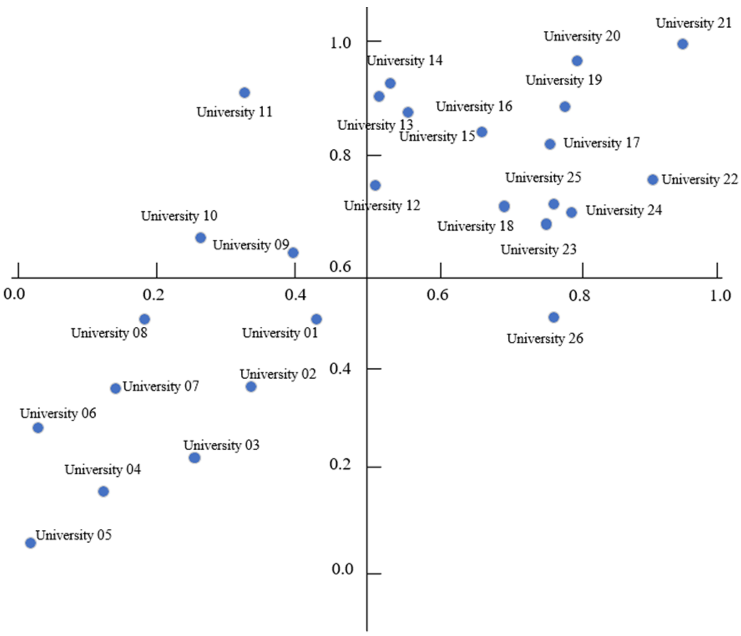

Fig. 3. Static matrix diagram of collaborative innovation achievement transformation efficiency of college students

Table 1. Improvement paths of collaborative innovation ability of college students

Ability Level		Collaborative Innovation Ability Level					
		High		Middle		Poor	
Conditions		Path 2a	Path 2b	Path 1	Path 5	Path 3	Path 4
Internal management factors of universities	Education and teaching quality	◎	◎	◎	®	®	®
	Construction of teaching staff	◎	◎	®	◎	®	®
	Practical experimental conditions	◎		◎	®	®	®
External environmental factors	Industry-university-research cooperation	◎	◎		®	◎	®
	Social demand	◎	◎	◎	◎	◎	®
Random interference factors	Individual differences of students		◎	◎	◎	®	◎
	Information technology change	◎	◎	◎	◎	◎	◎
	Economic factors	◎	◎	◎	◎	®	◎

Table 1 was used to analyze the paths for improving the collaborative innovation ability of college students under different conditions. After dividing the conditions into internal management factors of universities, external environmental factors, and random interference factors, it was found that the improvement paths of collaborative innovation ability level required:

Internal management factors of universities: strengthen education and teaching quality, construction of teaching staff, and practical experimental conditions.

External environmental factors: strengthen industry-university-research cooperation, and pay attention to social demand.

Random disturbance factors: pay attention to individual differences of students, adapt to information technology change and economic factors.

This paper drew the following conclusions based on the analysis of these paths: in order to improve the collaborative innovation ability of college students, the comprehensive effects of internal management factors of universities, external environmental factors, and random interference factors needed to be paid attention, particularly education and teaching quality, construction of teaching staff, practical experimental conditions, industry-university-research cooperation, and social demand. Different improvement paths could be chosen under the conditions of different ability levels. For example, college students with high collaborative innovation ability further improved their ability through Path i; students with middle ability level chose Path 2a or 2b based on specific circumstances. Universities needed to pay attention to random interference factors, such as individual differences of students, information technology change, and economic factors, in order to ensure the stable improvement of collaborative innovation ability. Then universities should formulate feasible collaborative innovation ability improvement strategies based on their own actual situations, pay attention to internal management factors, fully utilize the external environment and deal with random interference factors.

Table 2. Improvement paths of collaborative innovation achievement transformation ability of college students

Ability Level		Achievement Transformation Ability Level			
		High		Middle	Poor
Conditions		Path 1	Path 2	Path 3	Path 4
Internal management factors of universities	Innovation and entrepreneurship education	◎	◎	®	®
	Intellectual property protection	◎	®	◎	®
External environmental factors	Technical innovation and update	◎	◎	◎	®
	Industrial demand	®	®	®	◎
Random interference factors	Economic fluctuations	◎	®	®	®
	Competitive situation		®	®	◎

According to the Table 2, it can be found that the improvement paths of collaborative innovation achievement transformation ability require:

Internal management factors of universities: strengthen innovation and entrepreneurship education, and protect intellectual property right.

External environmental factors: pay attention to technical innovation and update, and moderately focus on industrial demand.

Random interference factors: pay attention to economic fluctuations and deal with competitive situation.

This paper drew the following conclusions based on the analysis of these paths: in order to improve the collaborative innovation achievement transformation ability of college students, the comprehensive effect of internal management factors of universities, external environmental factors and random interference factors needed to be paid attention, particularly innovation and entrepreneurship education, intellectual property protection, technical innovation and update, etc. Different improvement paths could be chosen under different achievement transformation ability levels. For example, college students with high achievement transformation ability further improved their ability through pathways; students with middle achievement transformation ability level chose Path 2 for improvement. Universities needed to pay attention to random interference factors, such as economic fluctuations and competitive situation, in order to ensure the stable improvement of the collaborative innovation achievement transformation ability. At the same time, universities should formulate feasible achievement transform ability improvement strategies based on their own actual situations, pay attention to internal management factors, fully utilize the external environment and deal with random interference factors.

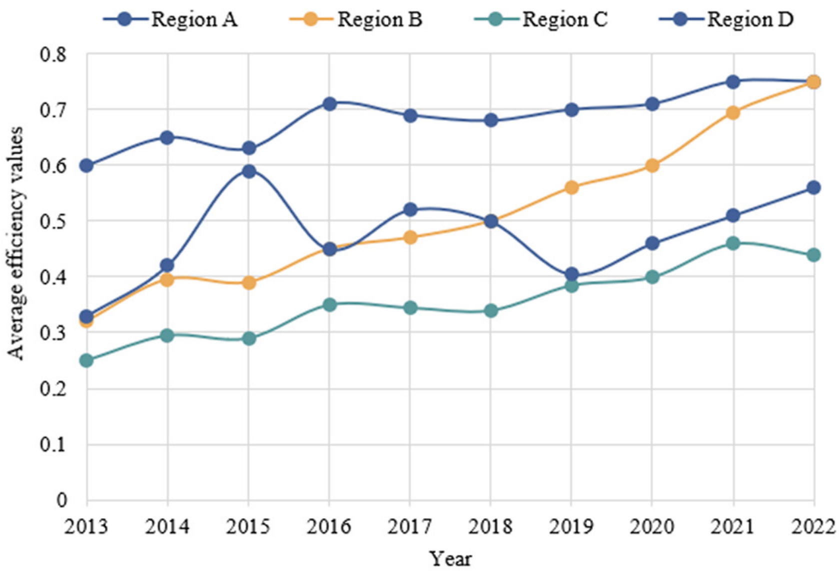

Fig. 4. Changes in average efficiency values of collaborative innovation achievement transformation of college students in different regions

By combining examples with changes in average transformation efficiency values in different regions in Figure 4, this paper analyzed the variation trend of the average efficiency values as follows:

Region A: the overall transformation efficiency showed an upward trend from 2013 to 2022, and increased from 0.6 to 0.75, with a growth rate of about 25%. During this period, the transformation efficiency remained relatively stable and maintained a high level in 2021 and 2022. Region B: the transformation efficiency also showed an upward trend from 2013 to 2022, increased from 0.32 to 0.75, and its growth rate more than doubled. During this period, the transformation efficiency increased year by year, with a significant increase especially from 2019 to 2022. Region C: the overall transformation efficiency showed a fluctuating upward trend from 2013 to 2022, and increased from 0.25 to 0.44, with a growth rate of about 76%. However, during this period, the transformation efficiency fluctuated significantly, showed a downward trend from 2018 to 2020, and started to recover in 2021. Region D: the overall transformation efficiency fluctuated significantly from 2013 to 2022. However, it showed an overall upward trend, and increased from 0.33 to 0.56, with a growth rate of about 69%. During this period, the transformation efficiency fluctuated significantly, especially significantly increased in 2015, and then fluctuated year by year. In summary, the collaborative innovation achievement transformation efficiency of college students in all four regions was on the rise. The efficiency growth of Regions A and B was relatively stable, while significantly fluctuated in Regions C and D. Among those regions, Region B had the largest growth rate and the most prominent performance. The transformation efficiency in different regions may be influenced by various factors within the region, such as education quality of universities, innovation and entrepreneurship policy, and industry-university-research cooperation. Therefore, it is necessary to analyze and take corresponding measures based on specific situations to improve the efficiency.

5 Conclusion

This paper studied the collaborative innovation ability cultivation of college students by improving the achievement transformation efficiency, and calculated the collaborative innovation and achievement transformation efficiency using three-stage DEA-Windows model. Then this paper elaborated in detail the calculation process of these three stages, namely, DEA-Windows analysis in the first stage, panel SFA in the second stage, and adjusted DEA-Windows analysis in the third stage. Based on the research needs of collaborative innovation ability cultivation of college students by improving the achievement transformation efficiency, this paper constructed an evaluation index system using Fare-Primont index model and Pastor method, and focused on output results and ability improvement of the achievement transformation. Combined with examples, this paper compared the collaborative innovation achievement transformation efficiency of college students at different stages and further drew a static matrix diagram of the transformation efficiency. In addition, this paper presented the necessary condition analysis results for the antecedent variables of collaborative innovation efficiency and achievement transformation effect of college students. Finally, this paper analyzed the improvement paths of collaborative innovation ability and collaborative innovation achievement transformation ability of college students, and provided analysis results.

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Article submitted 2023-02-13. Resubmitted 2023-05-02. Final acceptance 2023-05-05. Final version published as submitted by the authors.