Research Article

Analysis for Capital Investment Efficiency in Higher Education of Northeast China Based on DEA Model

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Abstract

In recent years, each country has raised investment in educational capital (EC) to a strategic level, and continuously increased investment amounts and investment allocation in the EC field in order to promote sustained economic prosperity and development. However, the scientific and profitability of investment have been relatively low at a low the investment efficiency. In response to this problem, this paper, by innovatively using the DEA model method, deeply studies various factors affecting investment in EC, and builds a quantitative index system for the EC investment efficiency in higher education. The research results show that there exist different problems about the EC investment efficiency in higher education of the surveyed provinces in Northeast China, e.g., some are caused by insufficient investment scale, and some by unreasonable investment allocation. This conclusion provides effective practical guidance for improving investment income.

Keywords

Educational Capital (EC) • Investment Efficiency Analysis • Data Envelop Analysis (DEA) Model •
Higher Education • Investment Allocation

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In recent years, the study of investment in higher educational capital has received extensive attention. In fact, the investment in higher education has promoted the improvement of talents' quality and the accumulation of human capital, which become the main driving forces for technological innovation and economic growth in many countries (Lambab, 2012). Scholars have explained how the investment of higher educational capital can transfer knowledge to economic growth in the form of technological innovation and management innovation (Basso & Funari, 2014). Also, in China, governments at all levels and social enterprises have increased their investment in higher education (Guo, Ma, & Zhou, 2012), such as raising the level of teachers, enhancing discipline construction and innovation, and funding scientific research innovation (Calik & Pehlivan, 2015). But, the above-mentioned large-scale, high-value investment in higher education can bring about different incomes and investment efficiency (Long & Li, 2011).

To avoid the waste of capital investment in higher education and improve the investment efficiency, some scholars have been committed to the evaluation and analysis of investment efficiency in higher education for the past few years. Ouellette et al. studied the investment efficiency of university teachers' per capita scientific research funds (Ouellette & Yan, 2014); Deacle *et al*., conducted a comprehensive analysis for the efficiency of capital investment in higher education from the aspects of college students' per capita education investment and student employment, student career development and alumni achievement (Deacle & Elyasiani, 2014), but the current analysis of investment efficiency has limitations. The EC investment in higher education only considers the college hardware and the teachers/students construction (Wang, Li, Sueyoshi, 2014). Besides, the evaluation factors of investment income are limited to the research results and the contribution of student alumni to social and economic development, and only the commonly used statistical method is used as the analytical method (Premachandraaabc, 2012). Therefore, for deeply analysing and evaluating the investment efficiency in higher education, this paper builds a CCR mathematical model based on the EDA model method, and introduces quantitative analysis indicators of capital investment, so as to quantitatively analyse the investment efficiency and find the reasons for the resulting inefficient investment. This shall provide guidance on improving investment allocation and increasing investment incomes.

This paper first expounds the basic theory using DEA model to analyse the investment efficiency in higher education, and establishes the mathematical model based on CCR model analysis to derive the efficiency value and deviation degree of important indicators for quantitative analysis of investment efficiency. Then, through sampling survey for the teacher construction, discipline construction and research & development Input of some universities in the north-eastern provinces, as well as the relevant data of the university development index, it establishes the DEA-based empirical analysis model of the basic decision unit DMU. Finally, the quantitative indicators of DEA efficiency analysis and projection analysis were calculated, to conclude the problems with investment in higher education capital of each province, which shall provide guidance for the subsequent improvement of investment efficiency and income.

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Analysis and evaluation for EC investment efficiency based on DEA model

EC investment based on DEA model

Data Envelopment Analysis (DEA) was proposed by operational research experts Charnes, Cooper, and Rhodes of the United States of America in the 1970s (Rodríguez, Mussati, & Scenna, 2011), to evaluate the relative efficiency between the Decision Making Units (DMU) with multiple input variables and multiple output variables multiple. Many scholars have continuously developed this model. The research object of the DEA model is the relative efficiency. In the evaluation process of DEA model, the first step is to obtain the efficiency value of each DMU by calculating the input and output variable data; the second step is to sort the efficiency value results of the first step and determine the efficiency of each DMU; the third step is to analyse the non-efficient DMU, determine the degree of non- efficiency and analyse the reasons. Therefore, the DEA model method not only evaluates the research object, but also provides further relevant information for optimization.

In general, when the DEA model method is applied to evaluates the relative efficiency and effectiveness between DMUs, it has strong redundancy for multiple input variables and multiple output variables, and those variables that are usually not easily quantified can also adopt the DEA model method. Therefore, in practical economic research, the DEA model method is more valuable than the commonly used statistical methods. The superiority of the DEA model method is mainly reflected in the following aspects: it supports for simultaneous parallel calculation of multiple input and output variables; input and output variable data can be different units of measure; no subjective weights need to be given, nor need to be specified about the relationship between variables; there will be no confusion between efficient and non-efficient DMUs, and a truly effective data envelope can be analysed; each DMU can be optimized instead of optimizing the entire statistical regression; it's not just sorting, but also provide specific suggestions for improvement.

In this paper, the DEA model method was applied to complete the following tasks: design a scientific and reasonable efficiency analysis and evaluation system; determine the DEA efficiency of each DMU, including technical efficiency and scale efficiency; calculate each DMU Projecting on the effective envelope surface, providing reference information for improving efficiency and management; analyse the correlation of each DMU to the efficiency of input and output variables and the correlation between the efficiency of DMUs; analyse the priority sequence of each DMU for macro decision making.

Mathematical Modelling of CCR Model

In the theories of the DEA model method, the most representative is the CCR model and BCC model. Under the given input and output variables, the CCR model, the BCC model, and the Additive model all can solve the problem for evaluating relative efficiency. CCR model and the BCC model are the most widely used ones. The CCR model is generally used to solve the problem with the assumed investment scale and investment income unchanged, and the BCC model is often used to solve the problem with the constant investment scale and the variable investment income. In this paper, it's assumed that the differences in the technical level of various

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regions in China during the same period are not significant, and that the same investment income should be produced by the same EC investment allocation in all regions of China, so the CCR model was selected to analyse the EC investment efficiency in higher education in this paper.

In the CCR model, given that there are n MDUs, the input and output variables of each MDU are the same, the number is m and s, then the input variable is $X_j=(x_{1j}, x_{2j},\ldots, x_{mj})^T$, the output variable $Y_j=(y_{1j}, y_{2j},\ldots, y_{sj})^T$, $j=(1,2,\ldots,n)$, the weight of the input variable is $u=(u_1,u_2,\ldots,u_m)$, and the weight of output variable is $v=(v_1,v_2,\ldots,v_m)$. Thus, mathematical modelling of CCR model is given as:

$$\begin{cases} \max \quad h_j = \dfrac{vY}{uX} \\ s.t \dfrac{vY}{uX} \leq 1 \\ \quad u \geq 1, \\ \quad v \geq 1 \end{cases}$$

(1)

In this model, h_j is called the effective efficiency value of the jth DMU relative to other DMUs. For the CCR mathematical model, it can be understood as: under the premise that the effective efficiency values of all other DMUs are lower than the maximum efficiency, the appropriate input and output variables are selected, so that the efficiency value of the Jth DMU is maximized, that is, for the jth DMU, without considering the constraints of other DMUs, the maximum efficiency that can be obtained by itself is achieved; if the j DMU cannot achieve the most effective efficiency under such conditions, then the decision unit itself is inefficient.

Analysis index of EC investment efficiency

To facilitate the analysis and calculation of the EC investment efficiency, the equivalent dual form of the CCR mathematical modelling formula was used, as shown in the following:

$$\begin{cases} \min \theta \\ \sum_{j=1}^{n} \lambda X + a = \theta X_0, a \geq 0 \\ \sum_{j=1}^{n} \lambda Y + b = Y_0, b \geq 0 \\ \sum_{j=1}^{n} \lambda_j = 1, j = 1,\cdots,n \end{cases}$$

(2)

From the above dual formula, the following conclusions can be drawn:

1) The necessary and sufficient condition for the DMU to be DEA efficient is if and only if $\theta=1$, $a=b=0$.

2) When the DMU is efficient for DEA, the technology and scale are both effective. That is, in order to obtain the same investment income, the investment input of various types of EC cannot be reduced in proportion, and the input of one kind of investment cannot be reduced or the output of a certain kind of income not increased. Compared with the weak DEA efficient and non-DEA efficient cases, its investment efficiency is better, and the investment and income ratios reach the optimal level and scale. The EC investment allocation, technical level and scale are all optimal.

3) If $\theta=1$, $a\neq0$, $b\neq0$, which indicates that the EC investment allocation is weak DEA efficient at a low investment efficiency. That is, in order to obtain the same investment income, the EC investment cannot be reduced in the same proportion, but some EC investment can continue to maintain the original investment income while reducing a, or investment income can increase with the EC investment unchanged.

4) If $\theta<1$, then the EC investment allocation is non-DEA efficient, i.e., in order to obtain the same investment income, the EC investment can be reduced in proportion; similarly, the investment income can be increased under the condition without increasing EC investment.

Empirical Analysis

Selection of variables and sample data

In this paper, the teacher construction, discipline construction and research & development Input of the universities in Heilongjiang, Jilin and Liaoning provinces in Northeast China were taken as the input variables of higher education EC investment; the development of universities as the output variable. Then, the relevant data of colleges and universities was extracted as sample data according to the statistical method. The DEA model method was applied to analyse and compare the efficiency of EC investment.

In this paper, the DEA model method used the input variables of the EC investment allocation in each province (the teacher construction, discipline construction and research & development Input) and output variable (university development) as one decision-making unit. Specifically, the Teacher Construction Index (TCI), Professional Discipline Index (PDI), and Research & Development Input Index (RII) in each province were taken as input variables for EC investment $X_j=(x_{1j}, x_{2j}, x_{3j})^T$, and the university development index (UDI) as an output variable $Y_j=y_{1j}{}^T$, as shown in the following:

Table 1
University Capital Investment and UDI

	Input variable			Output variable
	TCI	PDI	RII	UDI
HeiLongJiang	13.7	2.9	77	7.2
LiaoNing	13.9	2.4	82	7.3
JiLin	8.4	1.7	41	5.1

DEA efficiency analysis

Combined with the data of the above surveyed areas, the dedicated software DEAP was applied to calculate the efficiency value of the EC investment in the surveyed area (Table 2).

Table 2
DEA Efficiency of University Capital Investment

	Technical efficiency	Scale efficiency
HeiLongJiang	0.742	0.723
LiaoNing	0.785	0.721
JiLin	0.517	0.475

From the above table, the evaluation results of the DEA efficiency for the higher education capital investment allocation in the three provinces surveyed indicate that the technical efficiency and scale efficiency of Heilongjiang Province and Liaoning Province were both around 0.75, the investment efficiency of education didn't achieve the best, and there has been still room for improvement in the investment structure; in Jilin Province, the technical efficiency and scale efficiency of education investment were only about 0.5, with very unreasonable EC allocation. So, it is necessary to make structural changes of the inputs in order to give full play to the efficiency of investment in higher education.

DEA projection analysis

Based on the sample data of the surveyed province, the deviation indexes a and b were calculated as shown in Table 3. According to DEA projection analysis theory, the deviation index indicates that each DMU is projected on the effective envelope surface; the larger the value, the farther it is from the maximum value of the investment efficiency. If a deviate more from 0, then the technical factor of investment allocation needs to be considered for improvement; if b deviates more from 0, then it is necessary to consider the technical scale of investment allocation for further improvement.

Table 3
DEA Efficiency of Project Analysis

	a	b
HeiLongJiang	0.42	1.21
LiaoNing	1.03	0.93
JiLin	6.94	5.85

Based on the DEA projection analysis, Table 3 above shows that in Liaoning Province, it has a large deviation from the maximum investment efficiency in terms of technical scale, i.e., the higher education in this region has not yet reached the investment optimization, and more focus needs to be put on increasing the scale of investment in education. Whereas, the situation in Heilongjiang Province is exactly the opposite to Liaoning Province, and the follow-up needs to focus on the continuous improvement of the technical factors for investment in higher education, such as the optimization of investment allocation schemes etc. The status quo of higher education in Jilin Province is not optimistic, so it is necessary to make structural changes in terms of both scale and technology, that is, it should increase the scale of investment and optimize investment allocation, so as to ensure the sound development of higher education in this province.

Conclusions

This paper first proposes one basic point of view that the analysis and evaluation of the EC investment efficiency in higher education is a very necessary and important. Then, the basic theory of using DEA model to analyse the investment efficiency of higher education was expounded, and the mathematical model of CCR model analysis was established, to derive the important indicators for quantitative analysis of investment efficiency, namely the effective value θ and the degree of deviation a and b. Finally, a sample survey was conducted for the teacher construction, discipline construction and Research & Development Input of the

universities in the three provinces of Northeast China, as well as the relevant data of the university development index, and an DEA-based empirical analysis model of the basic DMU was established, to calculate the quantitative index data of DEA efficiency analysis and projection analysis; also, the current problems of higher education capital investment in each province were obtained. This shall provide direction and guidance for the subsequent improvement measures.

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