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Research on Performance Evaluation and Appraisal Methods of Asset Management in Public Universities Introducing Super-Efficient DEA Modeling

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ABSTRACT
A scientific, comprehensive and effective evaluation system of asset management performance of public colleges and universities in the context of high-quality development in the new era contributes to the "asset power" for the construction of high-level and high-quality development of colleges and universities. This paper takes 20 public colleges and universities in Province Y as research samples, and analyzes the asset management performance of public colleges and universities and its influencing factors through the super-efficiency DEA model and SFA model. The results show that the asset management performance of 13 public colleges and universities has reached DEA effective, and the rest of them are DEA ineffective. Human and material inputs have a significant positive effect on the asset management performance of public universities in terms of inputs, and both research income and number of patents have a significant positive effect on the asset management performance of public universities in terms of outputs at the 1% level. Relying on the scientific evaluation index system of asset management performance of public universities, establishing a high-level asset management team and clear budgeting and audit management are effective means to improve the asset management performance of public universities.

Keywords: super-efficiency DEA model, SFA model, university asset management, performance evaluation

1. Introduction

Schools have a pivotal role and significance in promoting the construction and development of the country, and making a reasonable evaluation of the performance of school asset management is an important factor in guaranteeing the effectiveness of its construction and development. Enhancement of the school's asset management awareness and ability is very necessary, which is also one of the

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necessary conditions for most of the domestic institutions to fully implement and implement the construction of economical school and realize long-term development [1].

School asset management is mainly to adjust and manage the process of asset operation, to promote the accounting and input of assets, and to make the asset processing, configuration, profit, evaluation, monitoring and so on to realize the scientific and rationality [2-3]. This is a long-term work, the content is tedious, information is complicated, the management of various environments is different, but the ultimate goal is to achieve the optimal allocation of school resources and maximize economic benefits. School asset management is a necessary means of asset integration and rational allocation, but also to ensure the preservation and appreciation of the value of the assets and high yield, to achieve the total amount of the school's overall assets and the composition of the assets to further optimize the inevitable prerequisite [4-5]. In short, school asset management refers to the full utilization of schools, the rational allocation of different assets to operate the economic process, is to promote the development of school education implemented by scientific means. School assets can be categorized into fixed assets, current assets, intangible assets and other assets, which are huge in scale and diversified in asset sources [6]. The complicated types of assets bring challenges to management. For a long time, the school asset management adopts rough means, which lacks a set of complete and standardized comprehensive asset performance evaluation system as well as a corresponding sound management system [7]. In the process of asset management, schools cannot realize the correct allocation and use of assets, resulting in many assets failing to give full play to their roles, thus causing a large number of assets to be idle and increasing the cost of education [8-10]. The subordinate departments of the school want to have more and better facilities and laboratories for their own interests. In addition, some school assets cannot be shared. For example, the effective utilization rate of some schools' research patents is insufficient, and the lack of effective scientific argumentation and planning makes it very easy to have higher capital costs and the educational value of patents cannot be maximized [11-12].

With the further advancement of school reform, its asset management is becoming more and more important. Therefore, schools need to use standardized evaluation and assessment methods, establish assessment standards with input-output index as the core content, analyze and judge the results and efficiency of school asset management, compare the results of existing investigations, make objective and fair assessment, so as to adopt corresponding countermeasures in a targeted manner, form a reasonable and scientific constraints mechanism, and improve the performance of school asset management [13].

Literature [14] used hierarchical analysis to analyze the weights of multiple parameters in the performance of physical asset management, of which six parameters are the main factors, and used this result for performance management. Similarly, literature [15] used integral data mining to assess the performance of university laboratory equipment assets, firstly, the hierarchical analysis method to do the weight analysis of each index, and then through the gray system theory to explore the correlation between the indexes and the final performance, a comprehensive understanding of the laboratory equipment assets on the response of each index, can be ultimately a reasonable allocation of assets. In addition, the literature [16] constructed a performance evaluation system of state-owned assets in colleges and universities with multiple levels of asset management mechanism, configuration, use and disposal. The difference is that literature [17] and literature [18] developed a set of asset management performance evaluation index system, the former is for non-operational asset management, while the latter is for full-cycle asset management, and the latter evaluates the weights of the indexes based on hierarchical analysis, determines the asset policy emphasizing the standardization of assets and high efficiency, and then evaluates the performance of a university's asset management through the fuzzy comprehensive evaluation method. In the above evaluation, the management performance of different types of assets is mostly evaluated comprehensively based on the hierarchical analysis method, and the evaluation index system is established. There is a lack of a more comprehensive evaluation of university asset management performance, and the method of its assessment is not introduced. The super-efficiency DEA model is a nonparametric evaluation method that can calculate the economic output created by the management inputs of universities based on the input-output data, so as to assess the efficiency level of the school [19]. The best practice experience of each indicator of asset management performance is evaluated to understand asset management more comprehensively and to design a reasonable assessment method.

The current performance evaluation system of asset management in public colleges and universities has problems such as unclear construction logic, incomplete evaluation content, and difficulty in forming closed-loop management in management and evaluation work. Based on this, this paper will use the super-efficient DEA model to measure the performance of asset management in public universities, and use the SFA model to find out the relevant factors affecting the performance of asset management in public universities. And based on the analysis results, it proposes a path to improve the performance level of asset management in public universities, so as to realize the purpose of optimizing the asset allocation and improving the management level in public universities.

2. Performance Evaluation System for Asset Management in Public Colleges and Universities

In the context of high-quality development in the new period, China's higher education endeavor has entered the stage of high-quality development. Under the strategy of developing the country through science and education and strengthening the country through science and technology, the State has increased its investment in and construction of public university assets. The development of public university assets has gone through a stage from the rapid expansion of asset scale and the sharp increase in asset growth rate to the stage of focusing on the quality of development and the efficiency of use. The asset construction of public universities is no longer greedy for more, but pays more attention to the use of existing assets to improve efficiency and play a role. In order to effectively solve the problems of unclear rights and responsibilities, inconsistency of accounts and duplication of acquisition and construction in the asset management of public universities, the concept of performance management has been introduced into the asset management of public universities, with a view to enhancing the asset management performance of public universities through the means of performance evaluation.

2.1. Logical framework for evaluating asset management performance

2.1.1. Asset management in public higher education institutions. For public colleges and universities, the so-called asset management refers to the various types of assets it owns to carry out operational activities, including the organization, direction, coordination, supervision and control of assets. Specifically, the asset management of public universities can also be defined in this way, which refers to the asset managers of public universities using certain measures and means to make full use of the assets of public universities to guide and organize the whole campus to achieve the asset management objectives of an activity [20].

The goal of asset management in public colleges and universities is to realize the rational allocation of assets, enhance the efficiency of asset utilization, establish a sound asset management sharing platform, and maintain the safety and integrity of assets. Let the assets of public colleges and universities make outstanding contributions in the fields of teaching, research and development, social services, etc., to meet the needs of all aspects of the work of the school, and strive to serve the sustainable development of the school business.

At present, most public colleges and universities implement the management mode of “unified leadership, centralized management, classification and responsibility” for assets. Within public colleges and universities, assets are under the unified leadership of the president. At the same time, assets are categorized and classified for management, and the major asset management departments of the university need to fulfill their obligations in accordance with the law, effectively plan the process of asset use, and stipulate the authority for asset use. The major asset management departments need to formulate and organize the implementation of specific management methods for the assets under their charge in accordance with the requirements of the school management system, and are responsible for the management of the assets in the process of occupying and using the assets in a classified manner.

2.1.2. Logical framework for performance evaluation. In order to realize the performance evaluation of asset management in public universities, it is necessary to construct the corresponding performance evaluation index system, and the design logic of performance evaluation index can clearly present the design process of the index system as well as the interaction relationship between the relevant processes. This paper utilizes the performance management theory and the theory of asset life cycle management, from the perspective of "target-process", to show the generation path of "performance target-performance indicator", i.e., target level indicator→process level indicator→end level indicator, to construct a performance evaluation index system for public university asset management. End-level indicators, constructing a logical framework for the design of public university asset management performance evaluation indicators as shown in Figure 1. Target level indicators refer to the macro-level executable goals of the organization, which is the strategy and vision of the organization. Process-level indicators refer to the specific implementable tasks in each workflow of asset management, which are the specific tasks and actions of the organization. The end-level indicators are the corresponding metrics generated by refining the asset management workflows.

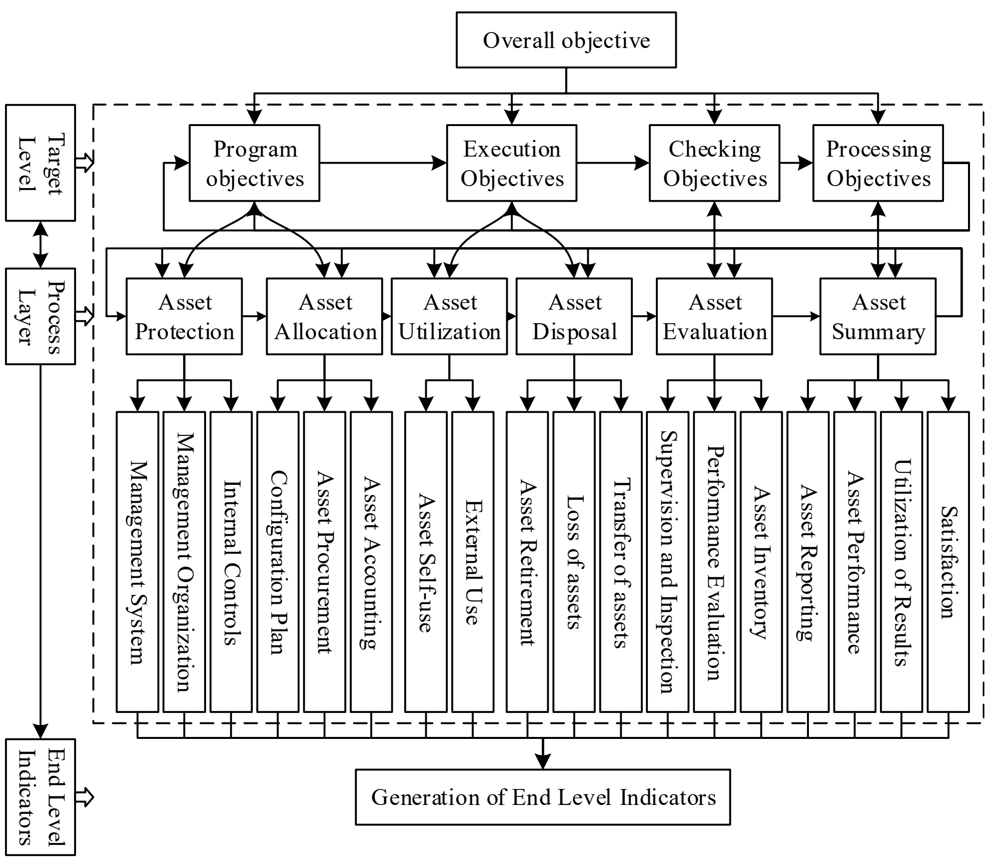

Fig. 1. Performance evaluation index design logic

As can be seen from the figure, three closed-loop, two levels work together to achieve the standardization and scientification of the performance objectives and management processes of the asset management of public colleges and universities.

First, the performance target layer, macro grasp the direction. The target layer, under the guidance of the general objective of asset management in public universities, contains four specific indicators such as program objectives. These four indicators are macroscopic and can be grasped from the overall direction to improve asset performance.

The second is the workflow layer, which pursues details in a microcosmic way. The process layer includes six processes such as asset protection, which can be subdivided into 18 specific workflows such as the management system. 18 processes involve various aspects of asset management, which can promote the efficiency of each detail process of asset management from the microscopic details to realize the high performance of the overall asset management.

Third, the target and process interaction, direction and details of the game. According to the logic of "plan, execute, check and process", the implementation of asset management in public universities and colleges to realize the combination of vertical management and horizontal management, reflected in the unity of direction and details.

2.2. System of indicators for evaluating asset management performance

2.2.1. Framework of the evaluation indicator system. Based on the target achievement of the asset management performance of public universities, through the existing relevant studies and a series of research, as well as on the basis of the analysis of the actual work, combined with the logical framework of the design of the evaluation indexes of the asset management performance of public universities, a system of evaluation indexes of the asset management performance of public universities is established. Its specific content is shown in Table 1, which mainly contains two dimensions of input and output, and the input indicators include building area, collection volume and total value of instruments and equipment, while the output indicators include the number of graduates, employment rate, scientific and technological writings, published papers, national projects, and income from the sale of patents.

Table 1. Asset management performance evaluation index system

Variable		Define	Code
Input	Architecture area	Campus building area	X1
	Collection quantity	The library is hidden in the library	X2
	Instrument equipment value	The value of the instrument for teaching research equipment	X3
Output	Number of graduates	College students	Y1
	Employment rate	Total employment rate	Y2
	Science and technology	The number of published science and technology books	Y3
	Paper publication	The total number of articles in various journals	Y4
	National project	All kinds of national projects that have been accepted	Y5
	Proprietary selling	The actual income of the sale of the patent	Y6

2.2.2. Data sources for evaluation indicators. In this paper, 20 public undergraduate colleges and universities in Province Y are selected as the research object, and the data come from the asset statement data of 2020-2023 in the platform of State-owned Assets System for Administrative Institutions in Province Y. The data are authorized by the Y Economic and Social Big Data Research Institute of University Y, and the rest of the data are searched by the authors themselves. The data of some indicators come from the official website of each university, such as the modules of "College Profile" and "Information Disclosure", and the departmental accounts and undergraduate teaching quality reports of the last three years related to the asset data of each university can be downloaded. In case of lack of data for an indicator of a certain school, the data of the neighboring years of the school are used as substitutes.

3. Asset Management Performance Evaluation Model for Public Colleges and Universities

Because public colleges and universities, as a kind of non-profit organization, are not driven by profit motive and lack of enterprise performance measurement indexes such as profit rate, market share, etc., the activity of evaluating the asset management performance of public colleges and universities is far more complicated than the performance evaluation of enterprises and other for-profit organizations. Starting from the goal of evaluating the asset management performance of public colleges and universities, this paper proposes to use the super-efficiency SBM model to measure efficiency, and explore the relevant factors affecting the asset management performance of public colleges and universities in conjunction with the SFA model, in order to provide guidance for the optimization of the level of performance of public colleges and universities in terms of asset management.

3.1. Super-efficiency DEA model

3.1.1. Principles of data envelopment analysis. The Data Envelopment Analysis (DEA) method is a non-parametric, non-random variable kind of analysis. It can be used to evaluate the relative efficiency of decision-making units, whether it is single-input multiple-output or multiple-input multiple-output, and the frontier surface can be constructed by using the method of linear programming, so that the efficiency of decision-making units can be better evaluated. The relative effectiveness of each decision unit can be measured by comparing the position of the decision unit and the frontier surface [21].

The traditional CCR model in dyadic form is expressed as:

$$s.t.\begin{cases} \min\beta \\ \sum_{j=1} \sigma_j W_{ij} + S^- = \beta W_{ik} \\ \sum_{j=1}^{m} \sigma_j q_{zj} - S^+ = q_{zk} \\ \sigma \geq 0, i = 1, 2, \cdots, n \\ S^+ \geq 0, S^- \geq 0 \end{cases} \tag{1}$$

where m independent decision-making unit (DMU) is assumed, where W represents the input variables, q represents the output variables, β represents the efficiency value of the DMU in the range of $0 \leq \beta \leq 1$, and σ represents the proportion of combinations of the j th decision-making unit in the reconstructed structure of an efficient DMU. S^+, and S^- are slack variables, assuming that the optimal solution of the model is σ^*, S^{+*}, S^{-*}, and β^*, when $\beta^* = 1$, indicates that the DMU is weakly efficient, when the number of outputs is reduced by decreasing the number of inputs to reduce each input variable in equal proportion, and the number of inputs is increased to increase the number of outputs in equal proportion. When $\beta^* = 1$, and $S^{+*} = S^{-*} = 0$, indicates that the DMU is strongly efficient, when the decision unit is in Pareto optimality. When $\beta^* < 1$, it means that the DMU is invalid. $\beta^* \in (0-1]$, the smaller the value of β^*, it means that the DMU is farther away from the effective, the worse the efficiency, and the closer the value of β^* is to 1, it means that the efficiency of the DMU is more effective.

The traditional CCR model is a production technology model based on the assumption of constant returns to scale. Although the CCR model can be used to calculate comprehensive technical efficiency, the efficiency results calculated by the CCR model include scale efficiencies because many industrial production units have not yet reached their optimal size.The BCC model assumes that the returns to scale are variable, which effectively offsets the negative effects of scale efficiencies to more accurately reflect the actual situation.The BCC model has a similar theoretical foundation to the CCR model but adds a constraint to the CRR dyadic model $\sum_{j=1}^{m}\sigma_j = 1(\sigma \geq 0)$. So the projection point of the BCC model and the output size of the DMU can be consistent.

3.1.2. Super-efficiency DEA modeling. The general DEA model considers DMUs to be divided into effective and ineffective states, i.e., there may be multiple cases with an effective value of 1, but it is not possible to further differentiate and rank the effective decision-making units. Some researchers envisioned and established the super-efficiency model, which solves the problem of not being able to compare the input and output efficiency values between effective decision-making units, and can precisely analyze and rank the DMU units that are simultaneously effective as indicated by the results of the traditional DEA model.

The definition of the super-efficiency DEA model is no different from the definition of the two traditional DEA models mentioned above, with the difference that the super-efficiency DEA model replaces the inputs and outputs of the j th decision unit with the combinations of inputs and outputs of the other $n-1$ nd decision unit when evaluating the A1st decision unit, thus not directly representing the j rd decision unit [22]. Therefore, if the returns to scale are set to be variable, the super-efficient DEA model in this case is:

$$\min \theta\left[\theta-\varepsilon\left(\hat{e}^T s^- + e^T s^+\right)\right]$$
$$s.t.\begin{cases} \sum_{i=1}^{n}\lambda_i x_i + s^- = \theta x_0 \\ \sum_{i=1}^{n}\lambda_i y + s^+ = y_0 \\ \sum_{i=1}^{n}\lambda_i = 1 \\ s^+ \geq 0, s^- \geq 0, \lambda_i \geq 0, i = 1,2,\ldots,n \end{cases} \tag{2}$$

1) Super-efficient BCC-DEA modeling. The super-efficient BCC-DEA model is:

$$\min \theta$$
$$s.t.\begin{cases} \sum_{\substack{j=1 \\ j=\lambda_0}}^{n}\lambda_j X_{ij} + S_i^- = \theta X_{j_0} \\ \sum_{\substack{j=1 \\ j=h_0}}^{n}\lambda_j Y_{rj} - S_r^+ = Y_{j_0} \\ \sum_{j=1}^{n}\lambda_j = 1 \\ \lambda_j, j = 1,2,\cdots,n \ And \ j \neq j_0 \\ S_i^-, S_r^+ \geq 0, i = 1,2,\cdots,m, r = 1,2,\cdots,s \end{cases} \tag{3}$$

2) Ultra-efficient CCR-DEA modeling. The super-efficient CCR-DEA model is:

$$\min \theta$$
$$s.t.\begin{cases} \sum_{\substack{j=1 \\ j\neq j_0}}^{n} \lambda_j X_{ij} + S_i^- = \theta X_{j_0} \\ \sum_{\substack{j=1 \\ j\neq j_0}}^{n} \lambda_j Y_{rj} - S_r^+ = Y_{j_0} \\ \lambda_j, j = 1,2,\cdots,n \ And \ j \neq j_0 \\ S_i^-, S_r^+ \geq 0, i = 1,2,\cdots,m, r = 1,2,\cdots,s \end{cases} \tag{4}$$

In the above model, the DMU efficiency value of the decision unit in the ineffective state is equal to the efficiency value of the corresponding DEA model; an effective state with a DMU efficiency value of r implies that even if it is increased by $(r-1)\times 100\%$ by the same proportion, it remains relatively effective in the entire sample set. The super-efficient DEA value represents the maximized value of the radius fluctuation while the decision unit is in a continuous efficient state. A large DEA value for a decision unit indicates that the decision unit will continue to be DEA efficient even if there is a large increase in inputs or a small decrease in outputs.

When $\theta = 1$ and simultaneously $S_i^- = 0$, $S_r^+ = 0$, the unit can be considered as DEA efficient and the technical efficiency of the unit is optimal at that moment. Therefore scaling down all inputs in the same proportion or scaling down an input or output individually is difficult to achieve without reducing output.

When $\theta = 1$ and $S_i^- \neq 0$ or $S_r^+ \neq 0$, the decision unit can be judged to be weakly efficient.

When $\theta < 1$, at least one of $S_i^- \neq 0$ and $S_r^+ \neq 0$ is correct, the decision unit is considered non-DEA effective. When $\theta < 1$ and $S_i^- \neq 0$ are correct, it means that the actual inputs can be reduced proportionally, while $S_r^+ \neq 0$ means that the inputs are too large for the same outputs or too small for the same inputs, which should be changed accordingly in order to ensure the DEA effective state. In addition to this, firms and organizations can still optimize the scale of operations by judging the size of $\sum_{j=1}^{n} \lambda_j$. I.e.:

1) When $\sum_{j=1}^{n} \lambda_j > 1$, reduce the scale of generation.

2) When $\sum_{j=1}^{n} \lambda_j < 1$, scale up.

3) When $\sum_{j=1}^{n} \lambda_j = 1$, it indicates no change in the returns to scale.

3.2. Stochastic Frontier SFA Model

3.2.1. Principles of the SFA model. The basic principle of the stochastic frontier function method (SFA) is to follow the method of production function and great likelihood estimation, by forming the corresponding production function and assessing the model parameters of the efficiency frontier surface, and finally determining the frontier function. Compared with the traditional efficiency measurement model, the advantage of this method is that it accommodates the consideration of stochastic factors, and at this stage, the exploration of the SFA model mainly focuses on the production function model, the stochastic frontier production function-panel data model and the stochastic frontier cost function model [23].

Take the production function model as an example, it is assumed that producer i uses input factors for the indicator output l when its production frontier function and output, the relationship between the efficiency Te is expressed as:

$$Output_i = f\left(x_i;\mu\right)\cdot Te_i \tag{5}$$

$$Te_i = Output_i \,/\, f\left(x_i;\mu\right) \tag{6}$$

where $Output_i$ refers to the measured output, x_i refers to the input factors, $f\left(x_i;\mu\right)$ denotes the frontier production function, i.e., the highest output boundary value that can be obtained by vector x_i, and technical efficiency Te refers to the ratio of production output to the highest output value. Based on the above equation, the stochastic production frontier function can be further constructed as:

$$Output_i = f\left(x_i;\mu\right)\cdot \exp\left(\tau_i\right)Te_i \tag{7}$$

where $\exp\left(\tau_i\right)$ refers to the stochastic factor, which is usually strongly influenced by producer behavior, and $f\left(x_i;\mu\right)\cdot \exp\left(\tau_i\right)$ refers to the stochastic frontier. Based on the above model, the efficiency expression can be transformed into:

$$Te_i = Output_i \,/\left[f\left(x_i;\mu\right)\cdot \exp\left(\tau_i\right)\right] \tag{8}$$

When a stochastic frontier cost function is determined, the error term of its model can be subdivided into two categories: observation error ε due to stochastic factors, and weak efficiency error δ reflecting the difference between the marked and the frontier. The expression for this is:

$$\mu_i = f\left(x_i\right) + \varepsilon_i - \delta_i, \delta_i \geq 0 \tag{9}$$

where, $f\left(x_i\right)+\varepsilon_i$ refers to the stochastic frontier cost and parameter estimation can usually be accomplished for it using partial least squares and likelihood estimation and matrix analysis. According to the above, the SFA model is able to select the method of residual estimation to measure the efficiency value.

3.2.2. SFA model parameter estimation. The stochastic part of the stochastic frontier model is peculiarly a composite error mechanism, a symmetric error v_i and a non-negative random variable μ_i, which complicates the parameter estimation of the stochastic frontier model, and the method of parameter estimation as well as the calculation of the technical efficiency is related to the assumptions of these two random variables [24].

It is usually assumed that the two random variables are independent of each other and uncorrelated with x_i, and in addition satisfy:

1) Zero mean $E\left(v_i\right)=0$.

2) Same variance $E\left(v_i^2\right)=0$, $E\left(\mu_i^2\right)=\mu$.

3) Uncorrelated $E\left(v_i v_j\right)=0$ to any $i \neq j$, $E\left(\mu_i \mu_j\right)=0$ to any $i \neq j$.

Under the above assumptions, we can estimate the parameters of the model using Ordinary Least Squares (OLS), Maximum Likelihood Estimation (ML), Corrected Ordinary Least Squares (COLS), etc., which requires that we also know the distributions of μ_i and v_i.

Some researchers have argued that the assumption of zero mean is not a necessary constraint, whereby a normal-truncated-tailed normal model is proposed with the following assumptions:

$$v_i \sim iidN\left(0,\sigma^2\right), U_i \sim iidN\left(\mu,\sigma_\mu^2\right), \mu_{i=}\left|U_i\right| \tag{10}$$

The technical inefficiency term μ_i is one-sided and it obeys a truncated-tailed normal distribution, a generalization of the half-normal distribution. The joint distribution of v_i and μ_i, satisfying the previous assumptions, is:

$$f(u_i, v_i) = \frac{2}{2\pi\sigma_u\sigma_v\Phi\left(\dfrac{u}{\sigma_u}\right)} \exp\left[-\frac{(u_i - u)^2}{2\sigma_u^2} - \frac{v_i^2}{2\sigma_v^2}\right] \tag{11}$$

and the log-likelihood function for the normal-truncated normal model is:

$$\begin{aligned} \ln L = {} & \frac{N}{2}\ln\frac{2}{\pi} - N\ln\Phi\left(\frac{u}{\sigma_u}\right) \\ & + \sum_{i=1}^{N}\ln\phi\left(\frac{u}{\lambda\sigma} - \frac{\varepsilon_i\lambda}{\sigma}\right) - \frac{1}{2}\sum_{i=1}^{N}\frac{(\varepsilon_i + u)^2}{\sigma^2} \end{aligned} \tag{12}$$

where N is the number of production units, $\lambda = \frac{\sigma_u}{\sigma_v}$, $\sigma^2 = \sigma_v^2 + \sigma_u^2$, $\sigma_u = \frac{\lambda\sigma}{\sqrt{1+\lambda^2}}$. Using the above log-likelihood function to construct the likelihood equations, the likelihood estimates for each parameter of the normal-truncated normal model can be obtained.

4. Empirical Evidence of Asset Management Performance Evaluation in Public Universities

After the launch of “double first-class” construction, the state has put forward new goals and higher requirements for the development of higher education, and the asset management of public universities, as the material guarantee basis for the construction of “double first-class”, has entered a new stage of evaluation and efficiency from the previous stage of laying the foundation and making up the short board. The stage of evaluation and efficiency. On the basis of analyzing the current status quo of asset management in public colleges and universities, it recognizes the significance of carrying out performance evaluation of asset management in public colleges and universities, and puts forward the content and methods of performance evaluation of asset management in public colleges and universities, in order to formulate a set of scientific, effective and perfect and reasonable performance evaluation index system to assess the management situation, and to continuously improve the level of asset management in public colleges and universities.

4.1. Example analysis of asset management performance

4.1.1. Indicator correlation analysis. Before using the super-efficiency DEA model to conduct the efficiency analysis of asset management performance evaluation in public universities, the first step is to satisfy the isotropy between the input and output indicators, and at the same time to satisfy the principles of comprehensiveness and streamlining of the indicators. Each indicator reflects the different nature of the evaluation object, and the strong linear correlation between indicators should be avoided and the indicators should be simplified under the premise of ensuring the purpose of evaluation. Public university asset management performance evaluation needs to rely on multiple inputs and multiple outputs in order to make the evaluation results both objective and fair, so it is necessary to analyze the correlation of the actual data, test the homogeneity of inputs and outputs, and at the same time merge or delete the indicators with large correlation coefficients, and try to retain the indicators that are well-defined, comprehensive, and play a vital role in the evaluation of the asset management performance of public universities, and to retain the indicators that are very representative and representative. At the same time, the indicators with large correlation coefficients are merged or deleted, and the indicators with clear definition, strong comprehensiveness and crucial role in the evaluation of the asset management performance of public universities are retained as much as possible in the process of selection and merging. SPSS software was used to calculate the correlation coefficients of the input-output items of the university asset management performance evaluation of the study sample, and its specific results are shown in Table 2. In the table, *,** represents significant correlation and extremely significant correlation at the 5% and 1% levels, respectively.

From the table, it can be seen that the public university asset management performance evaluation indicators established in this paper have a strong correlation between the different indicators at the 5% or 1% level shows a positive correlation, indicating that the indicators have homogeneous correlation, to meet the assumptions of the super-efficiency DEA model conditions, applicable to the model. However, the correlation coefficients between the various indicators are lower than 0.5, which indicates that there is no strong correlation between the various indicators, which together will have an impact on the evaluation of the performance of asset management in public universities, but do not have a strong impact on each other. Therefore, the various indicators selected in this paper can effectively reflect the level of asset management performance of public universities.

Table 2. Correlation analysis of input output indicators

	X1	X2	X3	Y1	Y2	Y3	Y4	Y5	Y6
X1	1	-	-	-	-	-	-	-	-
X2	0.426**	1	-	-	-	-	-	-	-
X3	0.313*	0.191*	1	-	-	-	-	-	-
Y1	0.238*	0.215**	0.238*	1	-	-	-	-	-
Y2	0.134**	0.223*	0.206**	0.271**	1	-	-	-	-
Y3	0.278*	0.275**	0.234*	0.224**	0.209*	1	-	-	-
Y4	0.315*	0.205*	0.248**	0.303*	0.114*	0.234**	1	-	-
Y5	0.242**	0.258**	0.219*	0.215**	0.137**	0.331*	0.243*	1	
Y6	0.431*	0.207*	0.185**	0.224*	0.152*	0.275**	0.212**	0.307**	1

4.1.2. Input-output efficiency analysis. The data of input indicators and output indicators of 20 public undergraduate colleges and universities in Province Y for each year from 2020 to 2023 are included in the super-efficiency DEA model to calculate the efficiency values of inputs and outputs in different years. The comprehensive efficiency distribution of inputs and outputs of different public colleges and universities' asset management performance is shown in Figure 2.

As can be seen from the figure, the 20 public undergraduate colleges and universities have the highest input-output efficiency in asset management performance in 2020 (1.476) and the lowest (0.078) in SX University, the highest input-output efficiency in 2021 (1.742) in SP University, and the lowest (0.097) in SX University, and in 2022 and 2023 in asset management performance the input-output efficiency were both highest in SP University, and SX University was at the bottom of the overall efficiency of asset management performance for four consecutive years. Further analysis reveals that the average efficiency of inputs and outputs in asset management performance of 20 public undergraduate colleges and universities in Province Y in 2020 to 2023 is generally good, among which there are 12 universities with relatively excellent efficiency (efficiency value ⩾ 1, which indicates super-efficiency), accounting for 60% of the total number of the study samples, which are mainly engineering and management colleges, and there are 5 universities with relatively average efficiency (0.5 < efficiency value < 1.0) colleges were 5, and there were 5 relatively poor (efficiency value ⩽ 0.5) universities, mainly in the humanities and social sciences.

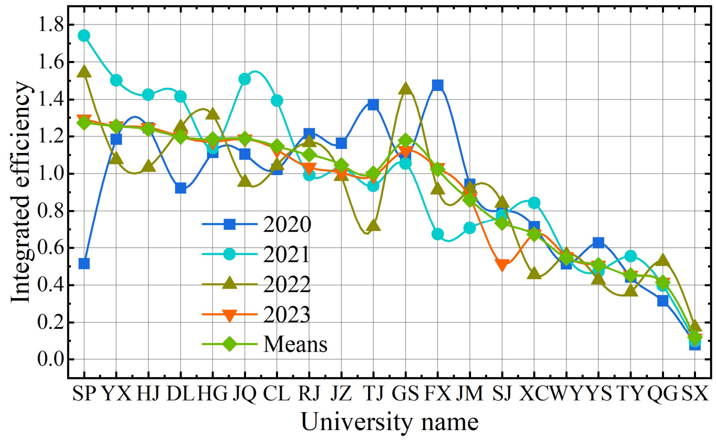

Fig. 2. Integrated efficiency distribution of input output

The plus or minus sign of the score after subtracting the input-output efficiency value in adjacent years represents the annual increase or decrease in the comprehensive efficiency of a university's asset management performance, respectively, from which the efficiency changes in the asset management performance of 20 public universities in different years can be calculated as shown in Figure 3.

Specifically, in 2020-2021, there are 12 universities in the 20 public colleges and universities that showed an increase in the comprehensive efficiency of inputs and outputs of asset management performance, of which the largest increase is in SP University, with a difference in the value of the comprehensive efficiency of 1.227, and there are 8 colleges that showed a decrease in the comprehensive efficiency of inputs and outputs of asset management performance, of which the largest decrease is in FX University, whose difference in the value of the comprehensive efficiency reaches - 0.803.In 2021-2022, there are 9 colleges that showed an increase in the combined efficiency of inputs and outputs of the asset management performance of 20 public colleges and universities, and the largest increase is GS University with a difference in the value of the combined efficiency value of 0.398, and the largest decrease is JQ University, with a difference in the value of the efficiency value of -0.554.In 2022-2023, there are 20 colleges and universities that showed an increase in the combined efficiency of inputs and outputs of the asset management performance of 20 public colleges and universities Input-Output Comprehensive Efficiency showed an increase of 12 universities, and the largest increase was SP University, whose comprehensive efficiency value difference was 0.777, and the largest decrease was FX University, whose efficiency value difference was -0.443.The Input-Output Comprehensive Efficiency value of the Asset Management Performance of Public Universities had a positive difference for four consecutive years between 2020 and 2023, which indicates that the level of the university's Asset Management Performance steadily improves year by year. In the sample of 20 public colleges and universities selected for this paper, there are no public colleges and universities where this phenomenon occurs. This indicates that each university in the research sample has certain problems in asset management performance, which leads to a decrease in the efficiency of its asset management performance evaluation.

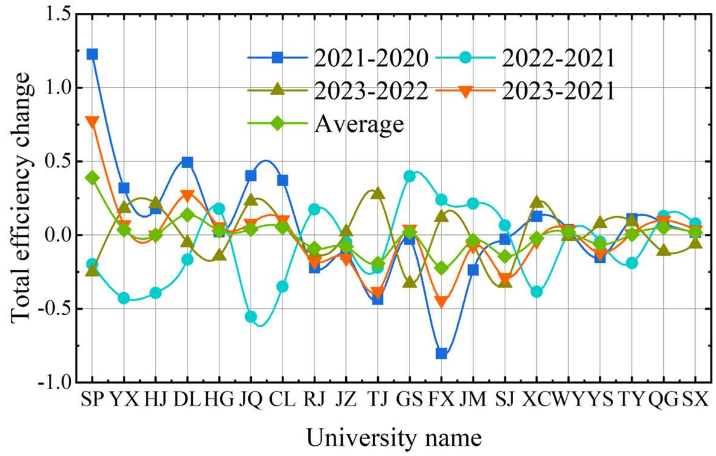

Fig. 3. The trend of comprehensive efficiency

4.1.3. Technical efficiency versus scale efficiency. Combined efficiency is the product of technical efficiency and scale efficiency, and thus combined efficiency is not effectively generated by DEA because of the values of technical efficiency and scale efficiency. In the DEA method, technical efficiency, also known as pure technical efficiency, is the ratio of optimal inputs to actual outputs on a production frontier with variable scale, and measures the technical and managerial level of the decision unit. Scale efficiency is the ratio of optimal inputs to optimal inputs on the production frontier with constant returns to scale to the production frontier with variable returns to scale for the decision unit, and measures the scale factor of the decision unit. Taking the data of asset management of 20 public universities in 2023 as an example, the technical efficiency and scale efficiency of fixed asset management of 20 public universities are analyzed by using the super-efficiency BCC-DEA model, and its specific results are shown in Table 3. Where Super, IE, PTE, SE and RTS represent super efficiency, comprehensive efficiency, pure technical efficiency, scale efficiency and scale reward, respectively, drs and irs represent increasing scale reward and decreasing scale reward, respectively, and - represents constant scale reward.

As can be seen from the table, the asset management performance of 20 public colleges and universities to achieve integrated efficiency DEA effective a total of 12, its integrated efficiency, pure technical efficiency and scale efficiency are 1, scale reward performance is constant. The level of asset management performance of this category of colleges and universities has reached DEA effective, reflecting that their asset management performance is more perfect, and can effectively realize the balanced development of input and output of asset management. Among the decision-making units whose comprehensive efficiency of asset management performance is not DEA effective, there are 3 colleges and universities whose pure technical efficiency is 1 and scale efficiency is less than 1, which indicates that these colleges and universities have reached the relative optimization of pure technical efficiency, but the scale efficiency still needs to be improved. That is to say, the fixed assets of these three colleges and universities are relatively high in technical level and management level, and the input elements of fixed assets have reached the relative optimal combination state, but there is still room for improvement in the scale of fixed assets, and the input of fixed assets can be increased or decreased proportionally according to the stage of the scale reward. When the returns to scale are in the increasing stage, other things being equal, an equal increase in the input factors will yield a higher proportion of output. When in the stage of diminishing returns to scale, an equal percentage increase in input factors will only result in a lower percentage of output. Among these three universities, only QG University is in the stage of increasing returns to scale, which should appropriately increase the inputs of fixed assets in equal proportions, while the other two universities are in the stage of decreasing returns to scale, at which time it is no longer possible to obtain outputs in equal proportions or higher proportions by continuing to increase the inputs, and should take the measure of equal proportional reduction of inputs to improve the efficiency of fixed assets. There are five colleges and universities whose pure technical efficiency and scale efficiency are less than 1 at the same time, which means that these five colleges and universities are not only technically ineffective, but also ineffective in scale. These colleges and universities cannot blindly expand the scale of construction and the amount of resource inputs, but should first improve technically, enhance the awareness of fixed asset management, improve the fixed asset management system, perfect the internal management of fixed assets, and enhance the level of management technology, and then improve the combinations of each input element and the scale of inputs and outputs on this basis.

Table 3. Technical efficiency and scale efficiency

University	Super	IE	PTE	SE	RTS
SP	1.292	1.000	1.000	1.000	-
YX	1.256	1.000	1.000	1.000	-
HJ	1.247	1.000	1.000	1.000	-
DL	1.198	1.000	1.000	1.000	-
HG	1.172	1.000	1.000	1.000	-
JQ	1.185	1.000	1.000	1.000	-
CL	1.127	1.000	1.000	1.000	-
RJ	1.034	1.000	1.000	1.000	-
JZ	1.006	1.000	1.000	1.000	-
TJ	0.989	0.827	0.948	0.872	drs
GS	1.124	1.000	1.000	1.000	-
FX	1.033	1.000	1.000	1.000	-
JM	0.869	0.512	0.537	0.954	irs
SJ	0.515	0.563	0.579	0.972	irs
XC	0.674	0.905	1.000	0.905	irs
WY	0.553	0.512	0.538	0.952	irs
YS	0.506	0.927	1.000	0.927	irs
TY	0.453	0.903	0.983	0.919	irs
QG	0.416	0.973	1.000	0.973	drs
SX	0.114	1.000	1.000	1.000	-

4.1.4. Analysis of relaxation variables. Relaxation variable analysis can further provide a specific basis for improvement in adjusting inputs and outputs to improve performance at relatively inefficient public colleges and universities. The slack variable analysis is used for relatively inefficient DMUs and provides information on the resource use of each inefficient DMU under current conditions to understand the extent to which the input resources and outputs fall short of the optimal performance targets, so as to analyze the room for improvement and the extent to which specific resource adjustments can be made. When a DMU reaches relative efficiency, it means that the DMU falls on the leading edge of efficiency and its inputs and outputs are optimally allocated, and its slack variables are all 0. If the DMU does not reach optimal efficiency, at least one of its slack variables is not 0, which means that its resource allocation is not optimal. Each public university can make adjustments of input and output variables to achieve the state of optimal efficiency through the relaxation variable analysis table, and the results of the analysis of the relaxation variables in each year are shown in Table 4 (effective DMUs whose relaxation variables are all zero are omitted).

From the table, it can be seen that the efficiency value can be increased by adjusting each input-output variable. In the case of TJ University, for example, the total value of teaching and research equipment and instruments is excessive, and this input can be adjusted so as to improve the relative efficiency, but the building area and the number of collections are not excessive, which indicates that the building area and the number of paper books in the library of TJ University are relatively insufficient in the context of the overall relative efficiency. As for the two DMUs, YS University and QG University, the building area, the number of collections and the total value of instruments and equipment have some redundancy, and the role of library paper books, teaching and research equipment and instruments is not revealed, such as the relative lack of investment in paper books and the relative lack of matching investment in research mobility, so that the facilitating function of outputs is not effectively realized. Therefore, by analyzing the slack variables helps to better assist public colleges and universities to realize the optimization and improvement of the asset management performance of public colleges and universities from multiple dimensions, and promotes the asset management performance of public colleges and universities to achieve DEA effectively.

Table 4. Results of annual relaxation variables analysis

University	X1	X2	X3	Y1	Y2	Y3	Y4	Y5	Y6
TJ	6.06	2.68	-2.41	0	0	0	0	0	0
JM	-0.79	4.73	3.08	0	0	0	0	0	0
SJ	1.24	-3.34	1.79	0	0	0	0	0	0
XC	0.57	2.51	6.75	0	0	0	0	0	0
WY	3.12	2.73	-3.84	0	0	0	0	0	0
YS	-0.23	-5.49	-2.49	0	0	0	0	0	0
TY	-2.51	3.86	-2.06	0	0	0	0	0	0
QG	-0.18	-2.63	-1.81	0	0	0	0	0	0

4.2. Factors affecting asset management performance

4.2.1. Variable Selection and Model Setting. In order to explore the influencing factors of the asset management performance of public universities, this paper takes the integrated efficiency value (IE) of the asset management performance of public universities obtained by the super-efficiency DEA model as the dependent variable, chooses the C-D function as the input-output function, and analyzes the relevant factors affecting the performance of the asset management of public universities from the perspectives of both input and output. The input indicators mainly include human resources (PR), financial resources (FR) and material resources (MR). The output indicators mainly include the number of graduates (GN), research income (SI), and the number of patents (PN).

Based on the SFA model given in the previous section, the parameter estimation is carried out by using the log-likelihood function of the normal-truncated normal model through FRONTIER software. Its specific research model is as follows:

$$IE_{it} = \alpha_0 + \alpha_1 PR_{it} + \alpha_2 FR_{it} + \alpha_3 MR_{it} + v_{it} - u_{it} \tag{13}$$

$$IE_{it} = \beta_0 + \beta_1 GN_{it} + \beta_2 SI_{it} + \beta_3 PN_{it} + v_{it} - u_{it} \tag{14}$$

where α_i, β_i represents the parameters to be estimated, respectively, the error term v_{it} represents the impact of shocks from random perturbations, and u_{it} is a technical inefficiency term that represents individual shocks.

4.2.2. SFA results in terms of inputs. Based on the SFA model constructed in the previous section, FRONTIER software was used to calculate the input indicators of asset management performance in public universities, and the results of SFA analysis in terms of inputs were obtained as shown in Table 5. The * in the table indicates that it is significant at 1% level of significance, the same as below.

As can be seen from the results in the table, the SFA model developed in this paper leads to several key findings, firstly, when the u term in the model is significant at 1% level of significance, this indicates that technical efficiency will have a significant impact on the input performance of asset management performance in public universities. Second, the value of γ is 0.979 and significant at the 1% level of significance, suggesting that about 97.9% of the combined efficiency of inputs originates from efficiency of scale, while about 2.1% originates from random factors (e.g., environmental variables). Further analysis of the significance of the indicators revealed that financial resources (FR) had insignificant effect on the performance of asset management of public universities in terms of inputs, while human resources (PR) and material resources (MR) had significant positive effect on the performance of asset management of public universities in terms of inputs. Among them, material resources (MR) has the greatest impact on the input indicators of asset management performance in public universities, while the impact of human resources (PR) is relatively small. Therefore, public colleges and universities can consider prioritizing the improvement of inputs related to material resources when carrying out asset management, and then improve the comprehensive efficiency of asset management performance.

Table 5. Results of the SFA analysis of the input index

-	Parameter	Constant	PR	FR	MR
Influence function	-	α_0	α_1	α_2	α_3
	Value	1.063	0.127	-0.008	2.137
	T	6.348*	2.041	-0.042	1.746*
Residual estimation	Parameter	u	γ	Year	Sample
	Value	0.063	0.929	4	20
	T	5.371*	8.814*	-	-

4.2.3. SFA results in terms of outputs. Using FRONTIER software to calculate the output indicators of asset management performance of public universities, the results of the SFA analysis on the output side were obtained as shown in Table 6.

As can be seen from the table, the u of the SFA model established in this paper is significant at 1% level of significance, then it indicates that technical efficiency has a significant effect on the output aspect of the asset management performance of public universities. And the value of γ is 0.927 and significant at 1% level of significance, which indicates that 92.7% of the combined efficiency of the asset management performance of public universities is due to technical efficiency and scale efficiency, and 7.3% is due to stochastic factors (environmental and other factors). In addition, the selected indicator graduation number (GN) is insignificant, while research income (SI) and number of patents (PN) are both significant at the 1% level. Among the significant indicators on the performance of asset management in public universities in terms of output the impact of research income (SI) is relatively large, while the impact of the number of patents (PN) is relatively small. Therefore, the asset management of public universities can focus on research income and the number of patents in terms of output, so as to promote the comprehensive efficiency of the asset management performance of public universities can be improved.

Table 6. Results of the SFA analysis of the output index

-	Parameter	Constant	GN	SI	PN
Influence function	-	β_0	β_1	β_2	β_3
	Value	0.927	0.001	0.224	0.095
	T	3.236*	1.737	2.793*	4.067*
Residual	Parameter	u	γ	Year	Sample

estimation	Value	0.039	0.927	4	20
	T	1.724*	33.515*	-	-

4.3. Path to optimize asset management performance

4.3.1. Emphasizing performance management and evaluation. Performance evaluation, as the last link in the whole life cycle management of assets, can guarantee the virtuous cycle of university asset management when properly utilized. College managers should fully recognize the importance of this work, constantly improve the assessment methods, quantitative indicators and evaluation standards, and flexibly utilize the full amount of asset information stored in the big data asset management platform to assess and evaluate the asset management environment, management process, and management efficiency of the university. And the evaluation results are applied to departmental performance target assessment, individual rewards and punishments, and even position promotion, in order to enhance the awareness of asset management of all personnel, understand the degree of realization of the functional objectives of asset management, and improve the level of asset management.

In order to ensure the smooth implementation of asset performance management, universities should build a perfect performance evaluation index system, from the management environment, management processes and management efficiency of the three aspects of the whole life cycle of university asset management performance assessment. Among them, the management environment index is mainly for the university asset management system, support conditions, organizational structure, personnel team and other content evaluation standards, in order to reflect the normality and feasibility of the whole life cycle management activities. Management process indicators are the evaluation criteria for the management activities of each link in the whole process from formation, use to disposal of assets, including the management activities of asset budget, procurement, accounting, configuration, leasing and lending, foreign investment, inventory, conversion, information disclosure, etc., in order to understand the compliance and scientificity of the whole life-cycle management of assets in colleges and universities. Management efficiency indicators are the ultimate expression of the results of university asset management, and should evaluate the physical safety, utilization performance, configuration efficiency, cost savings, disposal benefits, results conversion, service satisfaction, etc. of university assets, in order to reflect the efficiency and innovation of the whole life cycle management of assets.

4.3.2. Developing a high-level management team. Establishing a team of talents with specialized skills is the key to improving the level of asset management in public universities.

First of all, raise the awareness of the importance of asset management and broaden the professional background of introduced asset management talents. Through the campus official website, the talent exchange market and other channels, recruit talents with professional backgrounds such as financial management, asset management, computer technology, information and statistics, etc., in order to adapt to the demand for high-quality development of asset management in public colleges and universities under the new situation. Secondly, the opening of professional and technical title evaluation channel, to provide asset management personnel with more space for development and more career enhancement path. Finally, regular training in theoretical knowledge and skills of asset management personnel is carried out to guide the asset management team to gradually establish the concept of asset management performance evaluation and update the knowledge related to performance evaluation of asset management personnel. It fully understands the methods of asset management performance evaluation and constantly improves the theoretical level and business skills of asset management personnel in performance evaluation.

4.3.3. Assurance of asset management and quality. Budget management is the first step in the whole life cycle management of assets, and colleges and universities should pay attention to budget approval and establish a sound budget management system related to the allocation of new assets.

First of all, before carrying out the budgeting work, the relevant personnel should analyze scientifically with the budget implementation of the school in the past. At the same time, the statistics of the previous year's fixed asset stock, increment, use of efficiency and departmental personnel, and combined with the needs of the unit's performance of duties, the status of the fixed asset stock, the reasonableness and necessity of reviewing the asset budget.

Secondly, colleges and universities should strengthen the core role of the school asset management department in asset management, clarify its management functions, give full play to its audit function in the departmental budgets and plans to determine the reasonableness and necessity of the budget plan, so as to promote the combination of asset management and budget management, scientifically coordinate the procurement of fixed assets in the whole school and determine the budget of the school department, so as to effectively promote the comprehensive development of asset management.

5. Conclusion

Fixed assets are an important part of university inputs, and improving their utilization efficiency is one of the important tasks of asset management in public universities. This paper evaluates the comprehensive efficiency, pure technical efficiency and scale efficiency of the asset management performance of public colleges and universities through the introduction and empirical analysis of the super-efficiency DEA model, and explores the relevant factors affecting the asset management performance of public colleges and universities through the SFA model. Relying on the evaluation results of the asset management performance of public colleges and universities, it is not only possible to determine whether their pure technical and scale efficiency is effective or not, and to determine the change of their scale remuneration, but also to analyze the specific ways to improve their management efficiency.

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