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Goal-oriented performance evaluation: an analysis based on the Malmquist-KDE indicator model

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ABSTRACT

Goal-oriented dimension is a new angle to solve the problem of universities' performance assessment. Firstly, designs an input-output index system, and calculates the Malmquist Index of the performance utilizes the panel data. Then, the non-parametric KDE graph is used in this research for further discussion of the differences of TFP changes. Meanwhile, a non-parametric KDE analysis is carried out respectively for TECHCH, EFFCH, PTEC, and SECH indexes. The Malmquist-KDE index model shows the results as follows: TFP is on a declining curve; the increased range of EFFECH is relatively smaller, while the annual growth of PECH and SECH are slow; the decrease of TFP is caused by the decrease of TECHCH; the general distribution gradually moves leftward, reflecting a fact that the TFP changes are decreasing progressively; the TFP change rate demonstrates obvious a skewed distribution; the patterns in the graph gradually shift from thin and tall ones into short and thick ones. Conversely, the changes of external factors force universities to improve their operations actively.

Keywords: Goal-Oriented, Assessment, Malmquist Index, Kernel Density Estimation

1. Introduction

In recent years, with China's economic development from the high-speed mode to high-quality mode, GDP growth rate continues to slow down, the financial gap is expanding, the central and local financial resources that can be used for higher education are far from being able to meet the financial needs of the development of colleges and universities, and the contradiction between the tight supply of funds and the growth of the financial needs of colleges and universities is becoming increasingly prominent, and it is gradually becoming a bottleneck restricting the development of China's higher education sector [1-3]. Many colleges and universities reflect that the days are very difficult, it is difficult to balance the budget, and the most fundamental reason for these problems is that the budget management of colleges and universities can not adapt to the new economic normal of China's

financial revenue and expenditure contradictions are exceptionally prominent, the growth rate of budget expenditure of colleges and universities is much larger than the growth rate of national financial revenue, the budget balance is difficult [4-6]. As a teaching, scientific research and social service functions of universities, the efficiency of the use of its funds is directly related to the quality of teaching, scientific research results and the scale of schooling. At present, Chinese universities have the problems of disconnection between budgeting and university development goals, weak budget control mechanism, and lack of incentive mechanism, at the same time, the budget management of universities lacks effective evaluation and incentive mechanism, which leads to the waste of educational funds [7-9]. Therefore, changing the current budgeting mode of colleges and universities, integrating the concept of performance management into the whole process of budget management in colleges and universities, and establishing a result-oriented budget management model can effectively improve the contradiction between the tight supply of educational funds and the growth of the demand for funds for college and university operation [10-12]. It can be seen that, with the deepening of the reform of colleges and universities and financial budget reform, budget performance management has become the focus of financial management of colleges and universities and urgently need to be solved, colleges and universities should continue to strengthen the budget performance management, and constantly improve the efficiency of the use of funds to meet the rapid development of colleges and universities of the demand for funds [13-14].

With the further promotion and implementation of budget performance management, the assessment and evaluation of the budget performance of secondary colleges will inevitably become an important part of university management. The internal budget performance evaluation of universities is not only the basis for universities to improve the efficiency of internal resource allocation, but also an important part of the internal management and internal reform of universities [15-16]. Through relatively objective data records and technical statistics, the budget performance evaluation of second-level colleges and universities plays an important role in school management and development with its comparable, distinctive and scientific characteristics. At present, Chinese colleges and universities mainly adopt the traditional key performance indicators (KPIs) evaluation method and the evaluation method based on the efficiency measure in the target-oriented performance evaluation method, among which the evaluation method based on the efficiency measure includes the data envelopment analysis (DEA) and stochastic frontier analysis (SFA) [17-19]. Since the KPI method implicitly assumes that the input and output of each college can be enlarged or reduced in equal proportions, that a single KP1 is not enough to fully reflect the intention of the evaluated object, and that there is a risk of the Fox paradox, the budget performance data of each college can be further calculated dynamically by combining the Malmqvist-KDE indicator model, which can provide a more comprehensive understanding of the current problems in the budget management of universities [20-22].

The progress made by this research for existing studies is mainly reflected in the following aspects in view of the problems mentioned in previous literatures. First, financial resources run through the entire process of the running, management and development of universities, so it is an important and fundamental task to distribute financial resources reasonably. Second, the standards used to measure the financial resource distribution performance of universities must be symbolic, and closely related to the realization of the strategic goals of universities, representing the characteristics of the performance assessment of non-profit organizations. Third, an input-output indexes pattern that reflects the orientations of the university development goals is designed, and a Malmquist-KDE (Kernel Density Estimation)-based dynamic assessment method is proposed in this research in allusion to the characteristics such as smaller quantity of selected universities and unknown data parameter distribution. Panel data is used for dynamic study of the variation trends and influencing factors of the financial resource distribution performance of universities.

2.   Research Methods and Data Sources

2.1.   Research Methods

2.1.1.   Malmquist Index and Decomposition. The so-called Malmquist index is a main tool used for the dynamic DEA efficiency assessment, which is used to express the variations of the total factor productivity of decision-making units. According to the DEA research, the variations of total factor productivity (TFPCH) can be decomposed as efficiency changes (EFFCH) and technical efficiency changes (TECHCH) while returns to scale remain unchanged. EFFCH can be decomposed as pure technical efficiency changes (PECH) and scale efficiency changes (SECH). Please refer to Formula 1:

$$M_0\left(x_t, y_t, x_{t+1}, y_{t+1}\right) = \frac{s_0^t\left(x_t, y_t\right)}{s_0^t\left(x_{t+1}, y_{t+1}\right)} \times \frac{D_0^t\left(x_{t+1}, y_{t+1}|VRS\right)}{D_0^t\left(x_t, y_t|VRS\right)} \times \left[\frac{D_0^t\left(x_{t+1}, y_{t+1}\right)}{D_0^{t+1}\left(x_{t+1}, y_{t+1}\right)} \times \frac{D_0^t\left(x_t, y_t\right)}{D_0^{t+1}\left(x_t, y_t\right)}\right]^{\frac{1}{2}} \tag{1}$$

It indicates that the efficiency has improved if these indexes are bigger than 1, and it indicates the other way around if they are smaller than 1. It indicates that the efficiency stays unchanged if they are 1. No strict function relations are required with this method, nor should the data be non-dimensionalized and added with weights. It is capable of solving problems such as the difficulty of confirming the weights in the existing assessment system. Besides, the fact that the indexes are decomposable may help us to further calculate the changes of efficiency and technologies.

The application range of these indexes in certain contexts of universities is defined in this research in accordance with the characteristics of various indexes being decomposed in the analysis of Malmquist index. TFPCH refers to the financial resource distribution performance changes of universities. EFFCH and TECHCH represent the inner and outer factors related to financial resource distribution performance, respectively. Among them, inner factors mainly include the impact of financial management efficiency. Outer factors mainly include the support of government and bank, two major external stakeholders, to financial resource distribution. Moreover, PECH refers to the construction level of the inner control system of a university. SECH refers to the changes of the available financial resources scale of a university. Therefore, the use of Malmquist index may measure the inner and outer factors that affect financial resource distribution performance, and further explore the causes behind the changes of performance.

2.1.2.   Non-Parametric KDE. To further investigate the changes between years, the kernel density of TFP efficiency is estimated in order to describe the dynamic changes of performance between adjacent periods. First, as for data set $\{x_1, \ldots, x_i, \ldots, x_n\}$, the KDE function of fixed bandwidth is shown as Formula 2.

$$f_h\left(x\right) = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{h_n}\frac{1}{\lambda_i} \cdot K\left(\frac{x - x_i}{h_n\lambda_i}\right) \tag{2}$$

In the formula, Function K means weight and comes with features such as $K \geq 0, K\left(x\right) = K\left(-x\right)$, $\int K\left(x\right)dx = 1$. h ($h>0$) indicates the smoothing parameter. The smoothness is greater if this value is bigger. Normally speaking, dynamic changes shall be expressed as $\Delta f\left(x\right) = f_{t1}\left(x\right) - f_{t0}\left(x\right)$. However, the changes of kernel density function are decomposed into three parts with "counterfactual" analysis. Please refer to Formula 3:

$$\Delta f\left(x\right) = CD_1\left(x\right) + CD_2\left(x\right) + CD_3\left(x\right) \tag{3}$$

In the formula, $CD_1(x)$, $CD_2(x)$ and $CD_3(x)$ respectively represent the translation, extension and deformation of patterns resulted from the changes of the position of kernel density function while other factors are under control. The distribution varies in different years: first of all, the density function experiences a translational movement while its extendibility and shape are unchanged. Second of all, the density function extends while its mean value and shape are unchanged. Third, only the shape is deformed while its mean value and variance are unchanged. Among them, the translation of density function represents the changes of the performance of all samples, and rightward translation indicates the increase of average performance level. If the changes of variance, namely the changes of disequilibrium degree, extend towards both ends, it indicates the increase of variance, which is the first-order changes of performance function, indicating the increase of disequilibrium degree and decrease of general performance level. The changes of shape involve the second-order changes, which are complicated. The implication of performance at this time is difficult to be precisely defined. The amount of variation of different groups is different, leading to the distortion of distribution, and even phenomena such as "double-peak" or "multiple-peak". The advantages of KDE lie in the fact that there is no need to understand the situations of data distribution beforehand, and the characteristics of data distribution can be directly obtained from data samples themselves, avoiding the shortcomings of artificial parameter setting and determination.

2.2. Selection of Samples and Source of Data

The reason why Anhui Province is used as the case in this research is because Anhui has initiated and launched the "upgrading standards and dissolving debts" project in 2010, and the debts of the majority of universities have been dissolved in three years, while the appropriation per capita has witnessed a significant increase, which increased from 5,000 yuan / student to 12,000 yuan / student in a short period of time. The changes of financial environment, faced by provincial universities of Anhui at that time, are similar to those challenges that may possibly be encountered by universities of different places after the "double-top" is implemented. Therefore, the provincial universities of Anhui Province are selected as samples and the year of 2010 is used as the boundary to study the influence of the tremendous changes of policies one year before and one year after on the financial resource distribution performance of universities. It is good for the discovery of the potential influential factors on the construction input performance of the "double-top".

The panel data used in this research came from the financial statements of provincial universities of Anhui from 2008 to 2012 since financial statement is able to reflect the use of capital of a university in its financial years. There are 27 provincial baccalaureate universities in Anhui, and Hefei University is simultaneously managed by the province and the city, so the ways it receives fiscal appropriations are somewhat different from those of others. Also, Bengbu University wasn't a provincial university until 2012 when it was put under the control of the provincial education department, so four years of its financial history are missing. These two universities have been removed from the panel in order to ensure the consistency of data in the research. A total of 25 universities are selected as the study samples.

3. Performance Measurement based on Malmquist-KDE Index

3.1. Design of Input-Output Index

Indexes are selected from three aspects in this research in allusion to the characteristics of the financial operations of universities, which are financial resources, human resources and internal control. Among them, financial resources input include government input and university input. The former chooses "the annual spending of financial appropriation for public budget" as the index, while the latter chooses "the annual spending of the management fund of special financial account" as the index. Human resources input represent the number of financial personnel in a university. In fact, the

qualities and skills of these people are even more representative and difficult to be quantified. Therefore, the "total number of financial personnel" of the financial department of a university is chosen as the input index. Internal control input mainly refers to the maturity level of financial regulations, and "the number of newly developed internal control regulations" of a university is chosen as the index.

The design of output indexes is based on goal orientations. As public institutions, budgets of universities are being strictly utilized every year. Most budgets must be utilized within the year except some projects that span across multiple years. So, differences between universities cannot be told on the surface. Therefore, when we measure the performance of universities utilizing financial resources, we are mainly assessing their potential in reserving financial resources for future development. The potential is reflected in the amount of funds deposited that can be flexibly utilized, the ability to realize great-leap-forward development with debt leverage, the ability to win over more financial subsidies, and the scale merits brought by the expansion of their scale. "Utility fund" refers to the unrestricted assets of a university, which can be relatively used by the university arbitrarily. The "annual increase of utility fund" is chosen as an index in order to reflect the efforts of a university devoted in the increase of the amount of funds deposited. In the age of limited financial resources, debt financing served as an important source for universities to keep developing. But today, debt can still play a role as the leverage even if the financial resources are abundant today. With "the total scale of borrowing", the ability of universities to utilize debt leverage is reflected in this research. In addition to obtaining capital from banks, universities may also fully develop their soft power in scientific research and education, and obtain necessary funds from other departments or organizations such as financial department. Normally, these funds are beyond the preliminary budget made in the beginning of a year. For local universities whose budget is tight, they are an important source of fund for them to purchase large instruments and equipment. Therefore, the "values of equipment of which the unit price is above 200,000 yuan at the end of the year" index is chosen to reflect the ability of a university to use its own competitive advantages to obtain additional financial resources. The scale of university is the cornerstone for future development, so choosing "the values of buildings at the end of the year" may represent most of the values of the hardware scale of a university. In conclusion, there are 8 input-output indexes in total, meeting the optimal standard which specifies that the quantity of samples shall be at least three times of that of the total number of input and output variables. The credibility of DEA analysis is therefore improved. Those indexes are illustrated in Table 1:

Table 1. Selection of the input / output indexes of the financial resource distribution performance of universities

Type	Index	Index description
Input index	The annual spending of financial appropriation for public budget (yuan)	Government input
	The annual spending of the management fund of special financial account (yuan)	Self-input
	Number of financial personnel	Personnel input
	The number of newly developed internal control regulations of the year	Inner control input
Output index	The annual increase of utility fund (yuan)	The increase of the amount of funds deposited of a university
	Total scale of borrowing (ten thousand yuan)	The scale of the development leverage of a university
	The values of equipment of which the unit price is above 200,000 yuan at the end of the year (yuan)	The ability to use competitive appropriations
	The values of buildings at the end of the year (yuan)	The scale of the fixed assets of a university

3.2. Malmquist Index Dynamic Assessment

The 5-year panel data of 25 provincial universities of Anhui are entered into DEAP 2.1 for processing. An input-oriented method is employed to calculate the total factor productivity of the financial resource distribution performance of each university in different years:

Three characteristics are shown in financial resource distribution performance as we observe Table 2:

1) The total factor productivity (referred to as "TFP" hereinafter) is on a declining curve. Out of all 25 universities, only the change rate of TFP in AHU, ACMU and ANC is bigger than 1, indicating that the financial resource distribution performance of these three universities is advancing.

2) The increased range of EFFECH is relatively smaller, while the annual growth of PECH is 0.9%, and the annual growth of SECH is 0.5%, both of which are slow.

3) The decrease of TPF is mainly caused by the decrease of TECHCH. The changes of TECHCH are caused by the external factors related to the financial resource distribution performance of universities.

Table 2. Malmquist index and decomposition of the financial resource distribution performance of universities from 2008 to 2012

University	effch	techch	pech	sech	tfpch	08-09	09-10	10-11	11-12
ANU	0.993	0.684	1.000	0.993	0.679	0.564	0.754	1.077	0.464
AHU	1.080	0.971	1.000	1.080	1.048	1.482	1.039	1.744	0.449
AAU	1.136	0.778	1.122	1.012	0.884	1.076	1.472	0.492	0.785
AMU	1.000	0.956	1.000	1.000	0.956	1.188	1.089	0.633	1.019
AEU	1.147	0.841	1.121	1.023	0.964	0.972	1.028	0.490	1.768
ACU	1.060	0.821	1.036	1.023	0.870	1.185	1.184	0.948	0.431
BMC	1.062	0.731	1.025	1.036	0.776	0.911	1.098	0.591	0.612
WMC	0.877	0.729	0.942	0.931	0.640	1.053	0.715	0.686	0.324
ACMU	1.254	0.904	1.014	1.237	1.133	1.975	0.550	0.722	2.101
FNC	1.033	0.843	1.044	0.990	0.871	1.340	0.932	0.458	1.007
WEC	1.068	0.858	0.984	1.086	0.917	1.529	0.922	0.927	0.541
ANC	1.015	1.225	1.000	1.015	1.244	5.665	0.508	1.776	0.468
HNC	0.980	0.702	0.967	1.014	0.688	0.980	1.015	0.350	0.645
CZC	1.000	0.780	1.000	1.000	0.780	1.004	0.801	0.730	0.631
SZC	0.931	0.857	1.000	0.931	0.797	1.046	0.790	0.576	0.850
CHC	1.049	0.759	1.020	1.028	0.796	1.057	0.763	0.431	1.155
CHZC	1.013	0.839	1.000	1.013	0.850	0.997	0.830	0.621	1.017
TLC	0.974	0.837	1.000	0.974	0.815	0.666	0.941	0.725	0.970
ATC	1.000	0.918	1.000	1.000	0.918	1.012	0.833	0.779	1.082
HSC	0.872	0.800	0.987	0.884	0.698	0.945	1.018	0.457	0.540
AIU	1.000	0.879	1.000	1.000	0.879	0.873	1.101	0.839	0.742
HNC	0.904	0.734	0.953	0.949	0.664	0.994	0.774	0.440	0.576
ATU	0.981	0.943	0.971	1.010	0.925	1.184	0.709	0.837	1.039
HNU	1.014	0.806	1.067	0.951	0.818	0.813	1.118	0.626	0.787
AFU	1.000	0.667	1.000	1.000	0.667	0.730	0.749	0.720	0.502
Average	1.015	0.827	1.009	1.005	0.839	1.102	0.885	0.687	0.740

3.3. KDE Index Dynamic Assessment

Malmquist index offers general data that measure financial resource distribution performance. However, they cannot reveal more potential information. To better describe the distribution of TFP changes, the non-parametric KDE graph is used in this research for further discussion of the differences of TFP changes of universities in different years. The data source comes from the change indexes of different years in Table 2. Meanwhile, a non-parametric KDE analysis is carried out respectively for TECHCH, EFFCH, PTEC, and SECH (data to be retrieved if needed since the space is limited).

Please refer to Figure 1 for the kernel density estimation results of the TFP changes of 25 universities from 2008 to 2012. The figure shows three tendencies:

1) The general distribution gradually moves leftward, reflecting a fact that the TFP changes are decreasing progressively, indicating that as financial appropriations become higher annually, the increase of the financial resource distribution performance of universities is gradually slowing down. The results of financial resource operations are inconsistent with the increase of financial resource input, indicating that the distribution is of low efficiency.

2) The patterns in the graph tell us that the TFP change rate demonstrates obvious a skewed distribution, which has an obvious right partial distribution from 2008 to 2009, indicating that the

differences of the financial resource distribution performance level between universities are huge in the early stage of this research.

3) The patterns in the graph gradually shift from thin and tall ones into short and thick ones, which is a fact is consistent with the increase of financial input, indicating that the differences of financial resource distribution performance between universities are gradually narrowing, especially from 2011 to 2012, when Anhui implemented the "upgrading standards and dissolving debts" project. As a result, the appropriation per student is as high as 12,000 yuan, so more than 70% debts before 2009 were settled. Consequently, obvious pattern changes, and the leftward motion is stopped. Apparently, financial appropriation is of significant relationship to the changes of financial resource distribution performance.
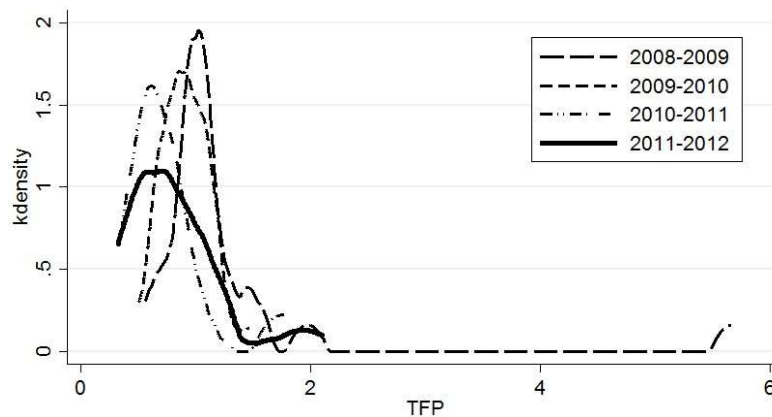
Fig. 1. TFP changes distribution from 2008 to 2012

Figure 2 and Figure 3 have shown the kernel estimation results of TFP change decomposition distribution. The distribution patterns show that the distribution of TECHCH is very similar to that of Figure 1, indicating that the main reason that leads to the decrease of financial resource distribution performance is an external factor. Unlike Figure 1, however, the wave crests of the first three periods still keep moving leftward, while the height of the peaks is increased, indicating that the external factor is not the main reason that leads to the narrowing performance differences between universities. Therefore, the reason that leads to the narrowing of differences may only come from the financial management efficiency of these incremental financial appropriations, indicating that the relevant management systems of these newly added financial appropriations have been appropriately developed and executed by the financial and education departments. As for universities, they shall manage the incremental financial appropriations under the guidance of superior department in charge. Nevertheless, the management level of various universities towards other financial resources, in addition to financial appropriations, is still greatly varied. Figure 3 shows that there are long rightward partial distributions in three periods respectively, which are 2008-2009, 2009-2010 and 2011-2012. The period of 2010-2011 is an exception because the main tasks of the "upgrading standards and dissolving debts" project in 2010 and 2011 are "no more loans, and some business income shall be used to pay back part of the debts, while the newly added funds for standard-improvement shall be all paid back for debts". With these measures in place, the operations of large value funds are consistent across the province, so there is no individual university with high financial management efficiency. However, there are certain universities of which the performance is better than the average in other periods.
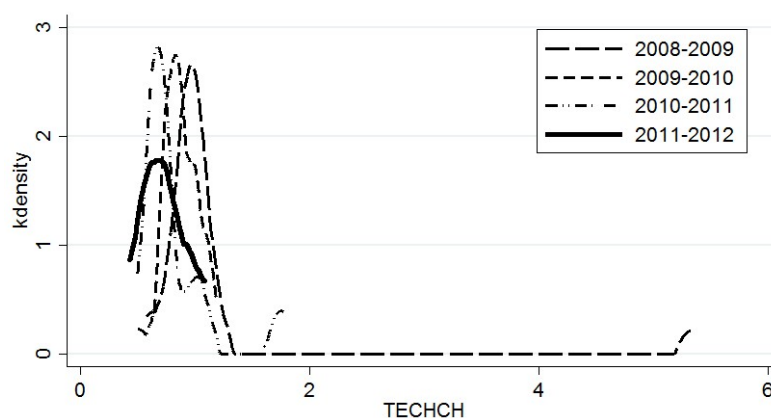
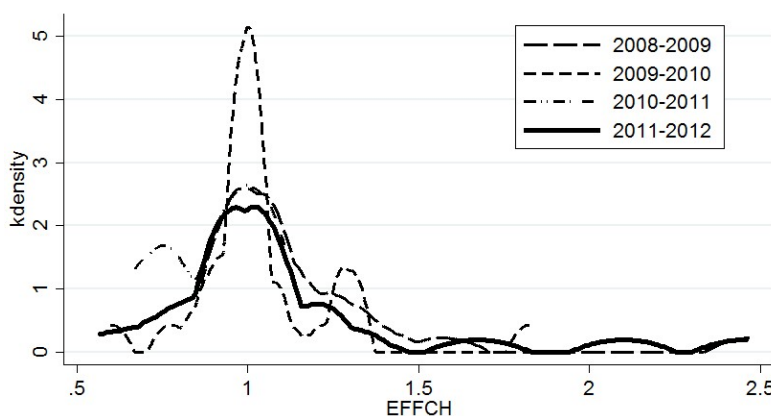**Fig. 2.** TECHCH distribution from 2008 to 2009

Fig. 3. EFFCH distribution from 2008 to 2012

Figure 4 and Figure 5 have shown the kernel density estimation results of the decomposition distribution of EFFCH, which can be used for further analysis of the reason that leads to the differences of financial management efficiency between universities. Figure 4 proved the speculation above that the financial management of various universities follow the regulations of the use of financial funds as stipulated by the superior department in charge, but there are significant differences between universities in undertaking revenues as well as the operations and management of other financial resources such as other financial subsidies. The distribution patterns in Figure 4 show that the patterns of 2008-2009, 2009-2010 and 2010-2011 are basically overlapped with obvious rightward partial distributions. Multiple peaks emerge in 2011-2012, which means that different universities have shown different abilities to adapt to the fact that their financial resources experienced a sharp increase, which are mainly reflected in the fact that some universities found it difficult to adapt to the reform of financial payment system. As required by the financial reform, the amount of financial funds to be paid by universities via fiscal integrative system increase sharply, so it becomes harder to pay financial funds. Only precise budget management is able to handle the situation. Obviously, some universities failed to adapt to the abrupt change, but those who have good budget management adapted to their roles rapidly. The distribution shown in Figure 5 is also a process from being thin and tall to being short and thick, indicating that the differences of universities in the scale of available financial resources are gradually narrowing, which means that the massive input of the financial department has achieved something, and the abilities of various universities to store financial resources for future development are strengthened.

The analysis above tells us that universities are still highly dependent on financial appropriations. The differences in financial resource distribution performance are mainly resulted from the different

abilities of different universities in financial resources operation. On the surface, the reason why the financial management abilities of universities are varied is because the financial departments of various universities have different understanding of financial policies and different attitudes towards risks. However, the root lies in the fact that incentive measures for the financial management behaviours of financial department are missing in the existing management systems of universities. In fact, most universities had a comfortable time when financial regulations were loose, and a financial department only had to ensure that the budget is successfully executed. There was no pressure, nor awareness of risk. Meanwhile, some other universities see their development goals as the orientations for the distribution of financial resources, and the expenditures in new campus construction, university upgrading and connotation construction go far beyond the support range of their annual financial budget. As a result, their financial departments are forced to develop elaborative budget, improve the use efficiency of special funds, and seek for sponsorship in order to obtain higher deposit interest rate or lower loan rate. They also make contacts with their own departments and colleges in order to obtain capitals other than financial appropriations so that financial resources can be continuously accumulated to fight against potential risks. Not only have they laid a solid financial foundation for themselves by doing so, but they have improved their financial management abilities as well. Therefore, their financial resource distribution performance does not decrease while adapting to the financial reform under the context of the new norms.
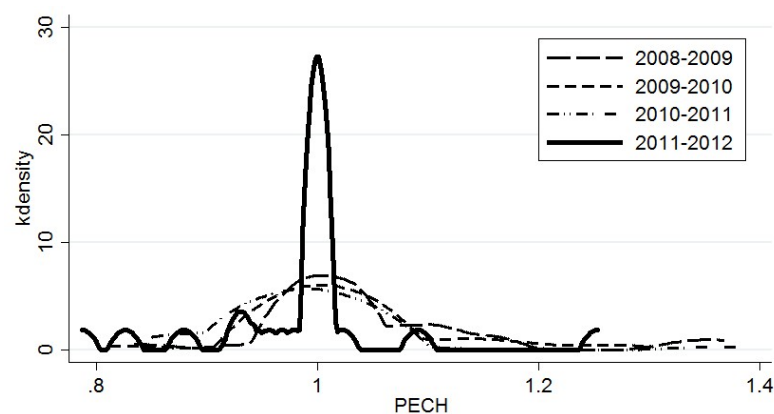

Fig. 4. PECH distribution from 2008 to 2012
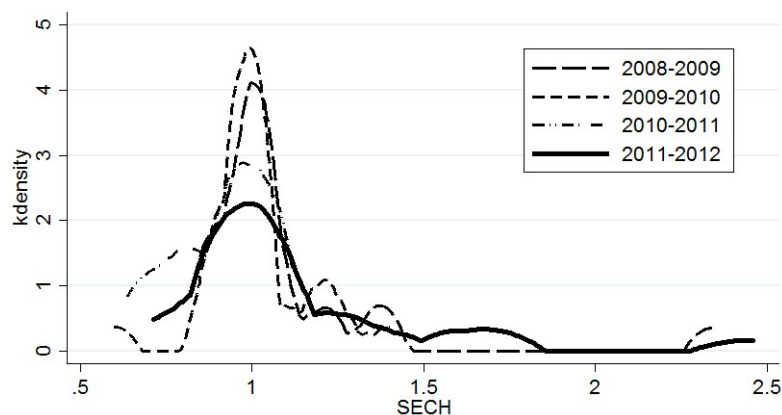

Fig. 5. SECH distribution from 2008 to 2012

4. Conclusion

The research found out that the financial resource distribution performance of universities is ultimately dependent on the subjective initiative of how universities operate financial resources. Under government control, the financial resource distribution performance is normally higher when the financial resources are abundant, especially those universities with stronger ability in financial resource distribution. The financial resource distribution performance would be better if there are more reserved available financial resources when the financial resources are insufficient. Otherwise, a university has to exploit its financial operation potential and coordination ability to survive a crisis.

The research conclusion tells us that universities nowadays should not only strive for more financial resources, but they also have to take risk regulation and expenditure restriction into consideration. As for risk regulation, in a short term, the government shall be more active, providing guidance for certain key parts, ensuring the safety and effectiveness of the use of financial funds, and strengthening the guidance of risk control of universities. In a long term, the inner control shall be strengthened through system construction. As for expenditure restriction, it shall serve as a breakthrough point so that the forcing mechanism of financial policies can be enhanced since the financial management efficiency of universities is still highly dependent on the policies made by relevant authorities. It is recommended to introduce the "negative list management pattern". On the one hand, we may make some room for system innovation. On the other hand, the control range of government towards universities can be greatly reduced, offering resource guarantee for universities to realize leaping development in the "double-top" construction.

Acknowledgements

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