Development of Assessment Model for Research Efficiency of Universities

Jong-Woun Youn and Kwangtae Park

Abstract Research in university is an essential part for national competitiveness and the foundation of knowledge and information of a society. This study assumed that the effective operation of limited resources by size of universities would be the plan for maximizing their effectiveness, and suggested grouping of similar universities by establishing a new classifying system. Based on new classifying system the current status of universities is assessed to help concentration on research activities for their target.

In this study, four models such as high efficiency expanding model (HEEM), high efficiency stable model (HESM), low efficiency stable model (LESM) and low efficiency expanding model (LEEM) were suggested through a practical analysis.

This chapter is based on the Ph.D. thesis of Dr. Jong-Woun Youn.

Keywords Research efficiency of universities • Assessment • DEA • Service productivity

J.-W. Youn (✉)
Center for Teaching and Learning, Korea University, Anam-dong, Seongbuk-Gu, Seoul 136-701, South Korea
e-mail: yjw333@korea.ac.kr

K. Park
Korea University Business School (KUBS), Anam-dong, Seongbuk-Gu, Seoul 136-701, South Korea
e-mail: ktpark@korea.ac.kr

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1 Introduction

1.1 Research Background and Objectives

Universities play an important role in the social development with intellectual growth. While "knowledge and information society" is an implicit expression of the modern society, universities that produce and transmit knowledge must be core institutions for national competitiveness. As such, the function of the university must be carried out accurately and effectively.

Functions of universities include knowledge production through researches and knowledge transmission through education. When interaction of education and research triggers knowledge transmission and expansion for a virtuous cycle of effectiveness and efficiency, it leads to national development as well as differentiated development of universities. This chapter focuses on the effective use of research resources for improving competitiveness in research areas, and it also suggests a framework of verifying efficient investments of research resources. Through suggested assessment models for university research, this study also sought a strategic improvement direction for efficiency.

1.2 Research Scope and Methodology

In this study, an analysis was made to 89 private universities out of 177 universities as of 2008. We included universities which provided data but considered only main campus if university had more than one campus. As a tool for empirical analysis, Data Envelopment Analysis (DEA) was used and cluster analysis was made to draw an implicit meaning of data. An empirical analysis by size of universities was carried out to suggest validity of an assessment model for university research (Kim and Lee 2008). As in Fig. 1 the research was carried out in three stages.

In the first stage, the assessment variables were chosen and efficiency was measured using DEA. Positive and negative output variables were used against input variables. In the second stage, a cluster analysis on universities of different sizes was carried out to compare operational characteristics of universities. Finally, in the third stage, we examined the variables which contribute to the efficiency and suggested improvement direction. In the first two stages, we show the individual result of efficiency and cluster analysis for each set of universities of different sizes. However, we show the overall result considering the validity of suggested assessment model in the third stage.

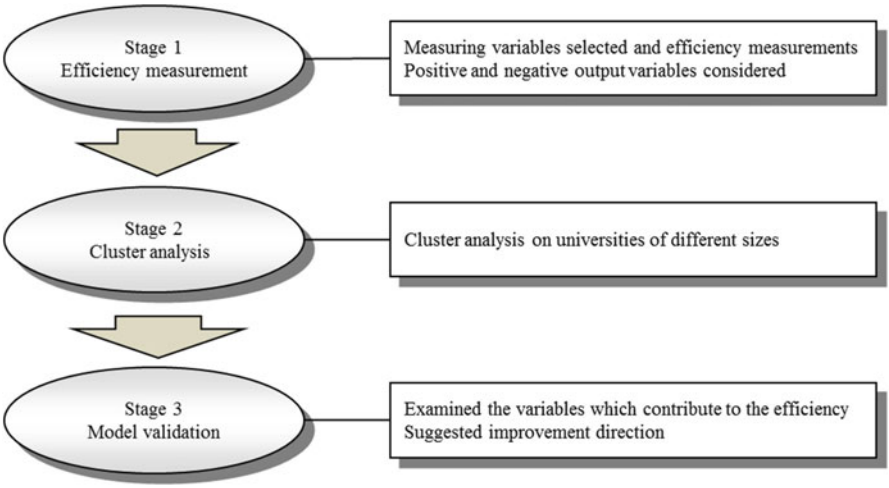

Fig. 1 Research procedures

2 Theoretical Background

2.1 Efficiency and DEA

Efficiency is an economic principle of getting the best effects with restricted resources (Lee 2003). Despite diverse usages of terminology, it is mainly divided into technical efficiency and allocative efficiency (Pindyck and Rubinfeld 2000). Technical efficiency is also called managerial efficiency which is to produce certain output with the minimum cost. Allocative efficiency can be explained as Pareto efficiency in which no resource allocation increases can be made without sacrifice of the other party in restricted resources (Banker et al. 1984). Efficiency measurement in DEA model is to measure relative efficiency of decision making unit (DMU) by means of comparison with other best organizations (Emrouznejad and De Witte 2010). This method has a basic presumption that, if organization has multiple input and output, efficiency must be measured not by absolute perspectives but by relative perspectives (Jeon et al. 2002).

DEA was originally developed by Charnes et al. (1978) for non-profitable purpose to measure relative efficiency through efficiency frontier, which DMUs empirically form. It measures efficiency by comparing DMUs by efficiency frontier, which organizations experience under some criteria applied to production possibility set (Kim and Kim 2001). It has recently been expanded to corporate efficiency analysis too (Emrouznejad et al. 2008).

As the university is a complicated organization of producing output using various resources, it is very hard to measure performance and efficiency. However, we can evaluate the efficiency by applying the DEA.

2.2 Negative DEA Model

The explanation of well-known DEA model which is Positive DEA model is found in the basic DEA book. We explain Negative DEA model which were actually used in this study.

Paradi et al. (2004) suggested the Negative DEA model. In Positive DEA model, it assumes the variability of size in terms of input orientation, but Negative DEA model assumes it as an output orientation. While Positive DEA models intend to increase efficiency using desirable input and output, Negative DEA model increase negative efficiency using undesirable input and output. The greatest feature of Negative DEA model is to attempt efficiency by finding an institution with high negative efficiency and by improving such output variables. But, this study defined research intensity as efficiency in Positive DEA model, and research expansion as efficiency in Negative DEA model Therefore, if there was high research expansion despite low research intensity, it was determined as poor operation. If there was high research intensity but low research expansion, it was regarded as low development orientation. If both research intensity and research expansion were low, it was considered as education focused development. If both were high, such university was regarded as research focused development.

Thus, variables of Positive DEA model are interpreted as a positive high efficiency. Meanwhile, variables of Negative DEA model are interpreted as negative high efficiency (Park 2009). In this regard, Positive DEA model and negative DEA model has an opposite outcome (Min and Jung 2005). Positive DEA model (1) and Negative DEA model (2) are shown as follows:

$$
\begin{aligned}
&\max E_k = \sum_{r=1}^{s} u_r y_{rjk} \\
&s.t. \sum_{i=1}^{m} v_i x_{ijo} = 1 \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} u_i x_{ij} \le 0,\ j = 1, \ldots, n \\
&\sum_{i=1}^{m} u_i x_{ij} = 1,\ j = 1, \ldots, n \\
&u_i \ge \varepsilon,\ i = 1, \ldots, m \\
&u_r \ge \varepsilon,\ r = 1, \ldots, s
\end{aligned}
\tag{1}
$$

$$
\begin{aligned}
&\max\ \theta_k - \varepsilon\sum_{r=1}^{s} s_r^+ - \varepsilon\sum_{i=1}^{m} s_r^- \\
&s.t.\sum_{j=1}^{n} x_{ij}\lambda_j = x_{ik} - s_i^-,\ i = 1, \ldots, m \\
&\sum_{j=1}^{n} y_{rj}\lambda_j = \theta_k y_{rk} + s_r^+,\ r = 1, \ldots, s \\
&\sum_{j=1}^{n} \lambda_j = 1 \\
&\lambda_j, s_r^-, s_r^+ \geq 0, \forall j, r, i, \theta_k
\end{aligned}
\tag{2}
$$

Compared with Positive DEA models, Negative DEA model considers negative condition such as insolvency of educational institution as well as financial institution. The reason to consider insolvency at university is that university may not get enough research support from government due to high competition and number of potential entering students is keep decreasing. It is not easy to get stable research support and thus needs efficient management of research fund. The existing Positive DEA model could not consider this situation, and thus we need to apply the Negative DEA model.

3 Analysis of Research Efficiency

3.1 Collected Data

As explained in Sect. 1.2, analysis of research efficiency was carried out for 89 private universities out of 177 universities in South Korea. The features of 89 private universities are in Table 1.

Variables in Table 2 were adopted for an empirical analysis (Rah and Kim 2005). Input variables included number of professors, students and employees. In order to reflect positive and negative effects together, positive output variables included research funding and purchase cost of books (Madden and Savage 1997) and negative output variables included liquid and fixed liabilities for research (Rah 2004).

The data collection was made from 2008 university statistics data kept by the Ministry of Education, Science and Technology in South Korea. Efficiency analysis was made using DEA Excel Solver, and statistical analysis was carried out using SPSS. Table 2 shows definitions of variables used in this study.

Table 1 Features of collected data (Ryu et al. 2006)

University by scale	Number of students	Number of universities
Small size universities	Less than or equal 5,000 students	18
Medium size universities	More than 5,000 students, less than or equal 15,000 students	59
Large size universities	More than 15,000 students	12
Total		89

Table 2 Definitions of variables

Division	Variable name	Unit	Variable description
Input variables	X1 Number of professors	Persons	Number of full-time professors
	*X*2 Number of employees	Persons	Number of full-time employees
	X3 Number of students	Persons	Number of full-time students
Positive output variables	Y1 Research funds	Ten million won	Total amount of research funding
	Y2 Purchase cost of books	Ten million won	Purchase cost of books
Negative output variables	Z1 Liquid liabilities for research	Ten million won	Research expenses to be reimbursed within 1 year
	Z2 Fixed liabilities for research	Ten million won	Research expenses to be reimbursed more than 1 year

3.2 Empirical Analysis

3.2.1 Research Model

Figure 2 suggested an assessment model for university research using cluster analysis of positive and negative efficiency values.

3.2.2 Measurement of Efficiency and Features for University Research

Efficiency measurement for university research was made by calculating efficiency value using positive and negative output and by comparing the value to calculate the operational orientation of university research. The assessment model for university efficiency was derived by figuring out the cluster characteristics of universities.

(*1*) *Analysis for research efficiency of small size university*

Stage 1: Comparison of efficiency value between Positive DEA and Negative DEA

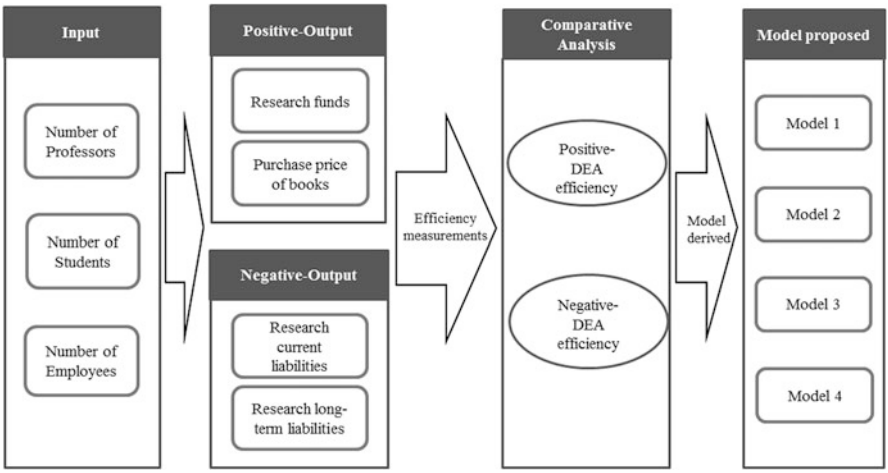

Fig. 2 Research model

The result of analysis for research efficiency of small size universities is shown in Table 3.

It is generally accepted that small universities focus on education. It is because they emphasize undergraduate courses rather than graduate courses, and students also seek employment rather than further studies after graduation. With such features in mind, Table 3 was examined.

39 % (7 universities) had higher positive efficiency value and 56 % (10 universities) had higher negative efficiency value. Exceptionally, there was one research focused university (5 %). From the average between positive and negative efficiency value, if research intensity was lower than research expansion, it could be argued that direct investment for research by small size universities was generally poor, and they would carry out inefficient operation with an excessive research investment.

Stage 2: Cluster features by means of cluster analysis

Table 4 shows a result of cluster analysis for research features of small size universities.

Figure 3 is scatter diagram for research efficiency of small size universities by combining positive efficiency value and negative efficiency value.

As a result of analysis from Table 5, cluster 1 has higher research intensity and research expansion, which means that it is specialized in research. Cluster 2 shows universities with a strong research specialized orientation. However, 11 universities belonged to cluster 3 and three universities belonged to cluster 4 out of 18 small size universities. Thus, they are below average in positive efficiency value. 78 % of universities belonged to such category, and three universities in cluster 4 (17 %) have higher negative efficiency value than average. They have poor research basis because of excessive investment over research size. Thus, it proves that 78 % of universities has a low research specialized orientation.

Table 3 Result of analysis for research efficiency of small size university

DMU	P-Efficiency	N-Efficiency
RS01	0.515 (△)	0.457
RS02	0.444	0.501 (△)
RS03	0.402	0.476 (△)
RS04	0.320 (△)	0.282
RS05	0.266	0.674 (△)
RS06	0.229	0.747 (△)
RS07	0.369	0.492 (△)
RS08	0.377	0.388 (△)
RS09	0.353 (△)	0.331
RS10	0.570 (△)	0.259
RS11	0.939 (△)	0.695
RS12	0.426	0.517 (△)
RS13	0.757 (△)	0.642
RS14	1.000	1.000
RS15	0.275	0.282 (△)
RS16	0.440	0.482 (△)
RS17	0.316	0.662 (△)
RS18	0.814 (△)	0.720
Average	0.490	0.534

(△) shows the higher efficiency value of each DMU

Table 4 Result of cluster analysis of small size universities

Cluster	DMU	Distance
1	RS14	0.000
2	RS11	0.103
	RS13	0.091
	RS18	0.041
3	RS01	0.119
	RS02	0.101
	RS03	0.070
	RS04	0.152
	RS07	0.095
	RS08	0.036
	RS09	0.094
	RS10	0.219
	RS12	0.113
	RS15	0.182
	RS16	0.082
4	RS05	0.021
	RS06	0.067
	RS17	0.056

(*2*) *Analysis for research efficiency of medium size universities*

Stage 1: Comparison of efficiency value between positive DEA and negative DEA

Table 6 shows analysis for research efficiency of medium size universities.

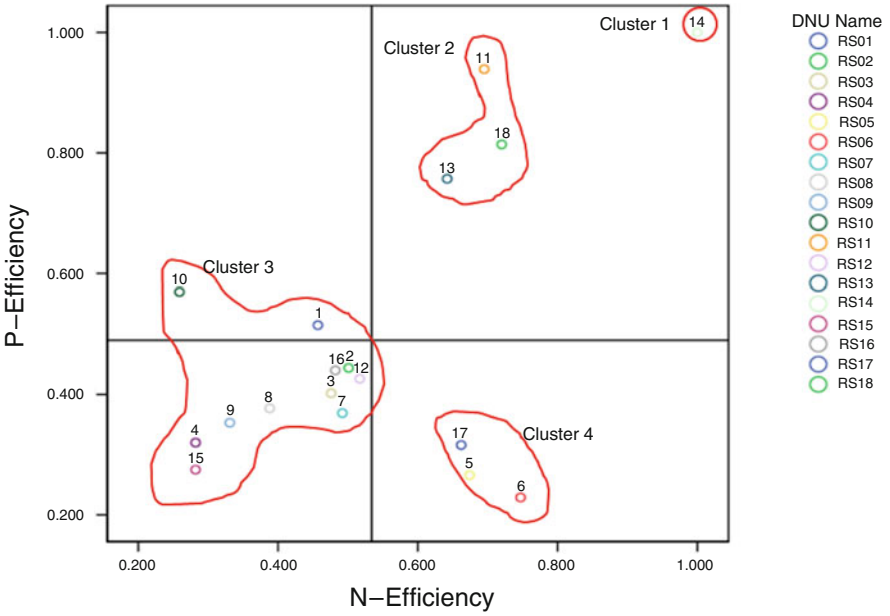

Fig. 3 Scatter diagram for efficiency of small size universities

Table 5 Number of cases for each cluster

Cluster	1	1
	2	3
	3	11
	4	3
Effective		18
Missing		0

Medium size universities have a focus both on education and research without a specific tendency to one of the two. While resources are allocated to both undergraduate and graduate schools, their research conditions are not enough to realize economy of scale. Undergraduate students tend to focus on employment after graduation, and a small number of students enter the graduate school. Table 6 shows an efficiency analysis for medium size universities. 32 % (19 universities) had higher positive efficiency values and 64 % (38 universities) had higher negative efficiency values.

Exceptionally, there were two research focused universities (3 %). From the tendency between positive and negative efficiency value, medium size universities also had a lower research intensity than a research expansion. It could be argued that direct investment for research by medium size universities was generally poor, and they would carry out inefficient operation with an excessive research investment.

Table 6 Result of analysis for research efficiency of medium size universities

DMU	P-Efficiency	N-Efficiency	DMU	P-Efficiency	N-Efficiency
RM01	1.000	1.000	RM31	0.237	0.468 (△)
RM02	0.272	0.353 (△)	RM32	0.353	0.545 (△)
RM03	0.783 (△)	0.550	RM33	0.363	0.621 (△)
RM04	0.134	0.615 (△)	RM34	0.383 (△)	0.356
RM05	0.297	0.337 (△)	RM35	1.000	1.000
RM06	0.351 (△)	0.294	RM36	0.330	0.480 (△)
RM07	0.313	0.400 (△)	RM37	0.218	0.541 (△)
RM08	0.830 (△)	0.597	RM38	0.676 (△)	0.482
RM09	1.000 (△)	0.371	RM39	0.294	0.689 (△)
RM10	0.576 (△)	0.453	RM40	0.355	0.542 (△)
RM11	0.415	0.514 (△)	RM41	0.441 (△)	0.343
RM12	0.201	0.310 (△)	RM42	0.379	0.391 (△)
RM13	0.502	0.755 (△)	RM43	0.275 (△)	0.256
RM14	0.327	0.480 (△)	RM44	1.000 (△)	0.569
RM15	0.262	0.284 (△)	RM45	0.109	0.354 (△)
RM16	0.259	0.392 (△)	RM46	0.212	0.370 (△)
RM17	0.264	0.370 (△)	RM47	0.525 (△)	0.491
RM18	0.271	0.584 (△)	RM48	0.501 (△)	0.447
RM19	0.774 (△)	0.440	RM49	0.153	0.368 (△)
RM20	0.440	0.703 (△)	RM50	0.809 (△)	0.521
RM21	0.127	0.375 (△)	RM51	0.421 (△)	0.328
RM22	0.215	1.000 (△)	RM52	0.190	0.248 (△)
RM23	1.000 (△)	0.697	RM53	0.435 (△)	0.393
RM24	0.271	0.413 (△)	RM54	0.135	0.326 (△)
RM25	0.225	0.297 (△)	RM55	0.668 (△)	0.286
RM26	0.348	0.366 (△)	RM56	0.222	0.257 (△)
RM27	0.169	0.219 (△)	RM57	0.073	0.501 (△)
RM28	0.467	0.577 (△)	RM58	0.386	0.770 (△)
RM29	0.333	0.358 (△)	RM59	0.875	1.000 (△)
RM30	0.803 (△)	0.448	Average	0.428	0.483

(△) shows the higher efficiency value of each DMU

Stage 2: Cluster features by means of cluster analysis

Table 7 shows a result of cluster analysis for research features of medium size universities.

Figure 4 shows scatter diagram for research efficiency of medium size universities by combining positive efficiency value and negative efficiency value.

As a result of analysis from Table 8, cluster 1 has higher research intensity and research expansion, which means that they are specialized in research. Cluster 2 shows universities with a strong research specialized orientation. But, 30 universities belonged to cluster 3 and 15 universities belonged to cluster 4 out of 59 medium size universities. Thus, they are below average in positive efficiency value. 76 % of universities belong to such category, and 15 universities in cluster 4 (25 %) have higher negative efficiency value than average. They have poor research basis because of excessive investment over research size. Thus, it proves

Table 7 Result of cluster analysis of medium size universities

Cluster	DMU	Distance	Cluster	DMU	Distance
1	RM01	0.042	3	RM34	0.116
	RM35	0.042		RM36	0.139
	RM59	0.083		RM41	0.175
2	RM03	0.064		RM42	0.117
	RM08	0.106		RM43	0.101
	RM09	0.225		RM45	0.158
	RM10	0.238		RM46	0.057
	RM19	0.064		RM49	0.114
	RM23	0.279		RM51	0.157
	RM30	0.045		RM52	0.133
	RM38	0.135		RM53	0.172
	RM44	0.204		RM54	0.136
	RM50	0.029		RM56	0.109
	RM55	0.251		RM57	0.242
3	RM02	0.006	4	RM04	0.229
	RM05	0.035		RM11	0.124
	RM06	0.104		RM13	0.189
	RM07	0.064		RM18	0.101
	RM12	0.081		RM20	0.109
	RM14	0.138		RM22	0.402
	RM15	0.072		RM28	0.115
	RM16	0.037		RM32	0.082
	RM17	0.014		RM33	0.005
	RM21	0.142		RM37	0.168
	RM24	0.057		RM39	0.093
	RM25	0.072		RM40	0.084
	RM26	0.081		RM47	0.212
	RM27	0.169		RM48	0.227
	RM29	0.066		RM58	0.145
	RM31	0.116			

that 76 % of universities had a low research specialized orientation. Compared with 78 % in small size universities, medium size universities have a slightly higher research specialized orientation.

(*3*) *Analysis for research efficiency of large size universities*

Stage 1: Comparison of efficiency value between Positive DEA and Negative DEA

The result of analysis for research efficiency of large size universities is shown in Table 9.

Large size universities focus on both education and research emphasizing specialized research area strategically, and the government also supports graduate school focused universities. Many resources are allocated to graduate schools, and they are easy to realize economy of scale in terms of research environment. Compared to medium size universities, many students seek graduate studies after graduation. Table 9 shows the result of efficiency analysis.

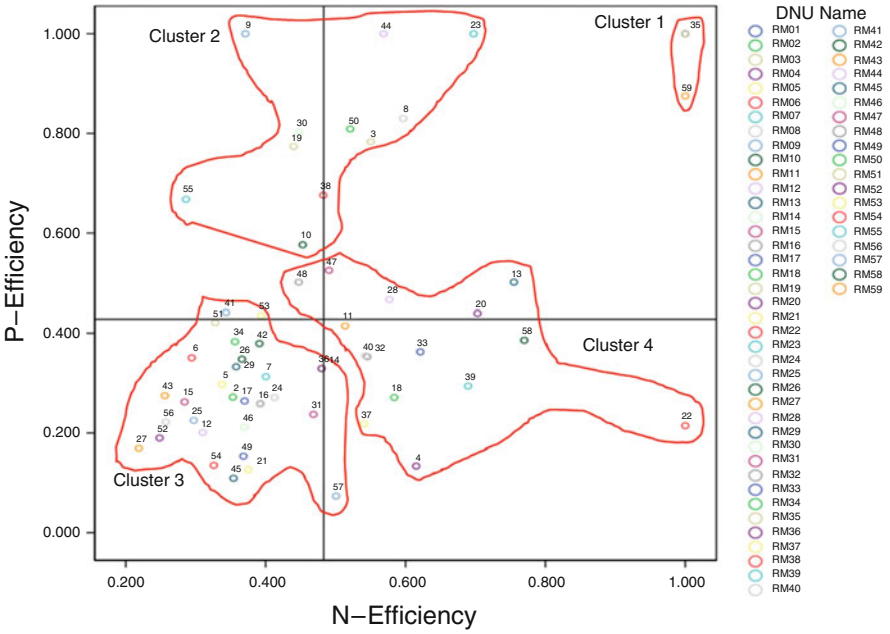

Fig. 4 Scatter diagram for efficiency of medium size universities

Table 8 Number of cases for each cluster

Cluster	1	3
	2	11
	3	30
	4	15
Effective		59
Missing		0

Table 9 Result of analysis for research efficiency of large size universities

DMU	P-Efficiency	N-Efficiency
RL01	0.599	0.689 (△)
RL02	1.000	1.000
RL03	0.557	0.789 (△)
RL04	0.856 (△)	0.508
RL05	0.459 (△)	0.409
RL06	1.000	1.000
RL07	0.630	0.683 (△)
RL08	0.451 (△)	0.391
RL09	0.617	1.000 (△)
RL10	1.000 (△)	0.477
RL11	0.336	0.523 (△)
RL12	1.000	1.000
Average	0.709	0.706

(△) shows higher efficiency value of DMU

Table 10 Large size universities clustering analysis results

Cluster	DMU	Distance
1	RL02	0.040
	RL06	0.020
	RL12	0.020
2	RL04	0.074
	RL10	0.074
3	RL05	0.054
	RL08	0.062
	RL11	0.115
4	RL01	0.101
	RL03	0.044
	RL07	0.111
	RL09	0.210

33 % (4 universities) had a higher positive efficiency value and 42 % (5 universities) had a higher negative efficiency value. Exceptionally, there were three research focused universities (25 %). From the tendency between positive and negative efficiency value, like medium size universities, large size universities also had a lower research intensity than a research expansion, but as for the average of efficiency value, positive efficiency value was higher than negative efficiency value. From such result, it could be argued that the strategic objective of research area is clear with a thorough control of research resources. Therefore, large size universities are generally active for reinforcing research capacity and directing basis of research.

Stage 2: Cluster features by means of cluster analysis

Table 10 shows a result of cluster analysis for research features of large size universities.

Figure 5 shows scatter diagram for research efficiency of large size universities by combining positive efficiency value and negative efficiency value.

As a result of analysis from Table 11, cluster 1 has higher research intensity and research expansion, which means that they are specialized in research. Cluster 2 shows universities with a strong research specialized orientation. Three universities belonged to cluster 3 and four universities belonged to cluster 4 out of 12 large size universities. Thus, they are below average in positive efficiency value. 58 % of universities belong to such category, and four universities in cluster 4 (33 %) have a higher negative efficiency value than average. They have poor research basis because of excessive investment over research size. Thus, it proves that 58 % of universities had a low research specialized orientation. Compared with 78 % in small size universities and 76 % in medium size universities, large size universities have a higher research specialized orientation.

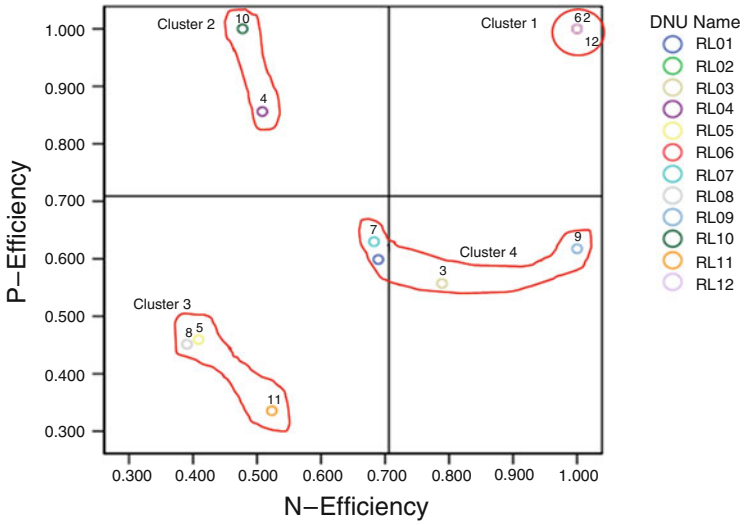

Fig. 5 Scatter diagram for efficiency of large size universities'

Table 11 Number of cases for each cluster

Cluster	1	3
	2	2
	3	3
	4	4
Effective		12
Missing		0

3.3 Stage 3: Validity of Assessment Model for Research Efficiency of Universities

Table 12 and Fig. 6 show the research efficiency by size implicitly. Mainly small size universities locate in three quadrants. Cluster 2 are on the average line of negative efficiency value without a clear feature. It is because there was no coherent strategic direction to improve research efficiency. On the other hand, for medium size universities, only cluster 4 locates on the average line of negative efficiency value. As for large size universities, 4 clusters are dispersed in 4 different clusters clearly. It demonstrates that if the size of universities becomes bigger, organizations for in-depth management on research area is segmented, and clear goal and strategic direction can be suggested coherently.

Figure 6 shows that when the size of universities becomes bigger, the efficiency of research area is marked in 4 different clusters clearly. This implies that the large size universities tend to realize a coherent policy. Thus, research efficiency of university can be expressed in four different characteristics. Based on such analysis, four models will be suggested to assess research efficiency of a university.

Table 12 Cluster center trend analysis

	Small universities		Medium universities		Large universities	
Cluster	P-Efficiency	N-Efficiency	P-Efficiency	N-Efficiency	P-Efficiency	N-Efficiency
1	1.000	1.000	0.958	1.000	1.000	0.980
2	0.837	0.686	0.811	0.492	0.928	0.493
3	0.408	0.406	0.267	0.356	0.415	0.441
4	0.271	0.694	0.363	0.626	0.601	0.790

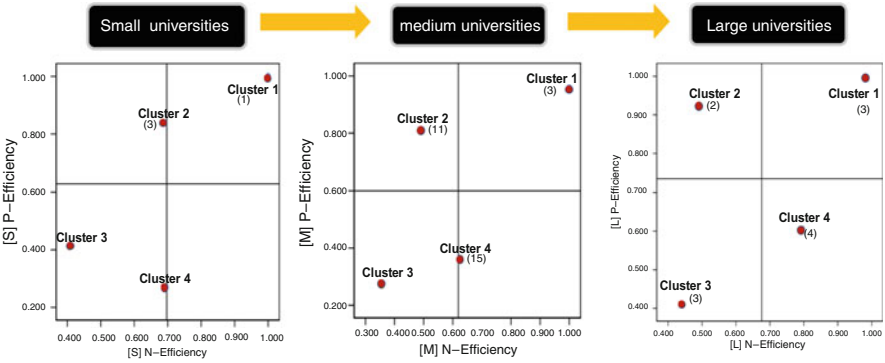

Fig. 6 Scatter plot for clusters

4 Conclusion

4.1 Findings and Implications

Michael Porter once remarked that "competitive advantage can be acknowledged when the competitor cannot copy it." Universities have higher entrance barrier in terms of market because they need large property and finance. However, it is hard to establish or keep an independent system for competitive advantage. Accordingly, it is desirable to seek specialization by effective and efficient input of research resources with selection and concentration (Ihm 2005). Instead of any overlapping investment and excessive investments, it is recommended to seek an appropriate investment for basis in research area.

Thus, we established assessment model for research efficiency of university for basis of research and for specialized development by figuring out the current status in research areas (Youn and Park 2009). As in Fig. 7, four models such as high efficiency expanding model (HEEM), high efficiency stable model (HESM), low efficiency stable model (LESM) and low efficiency expanding model (LEEM) were suggested through a practical analysis.

The model defined efficiency in positive DEA model as research intensity and efficiency in negative DEA model as research expansion and indicated the result of combination in clusters to assess the status of each university (Min and Kim 2005).

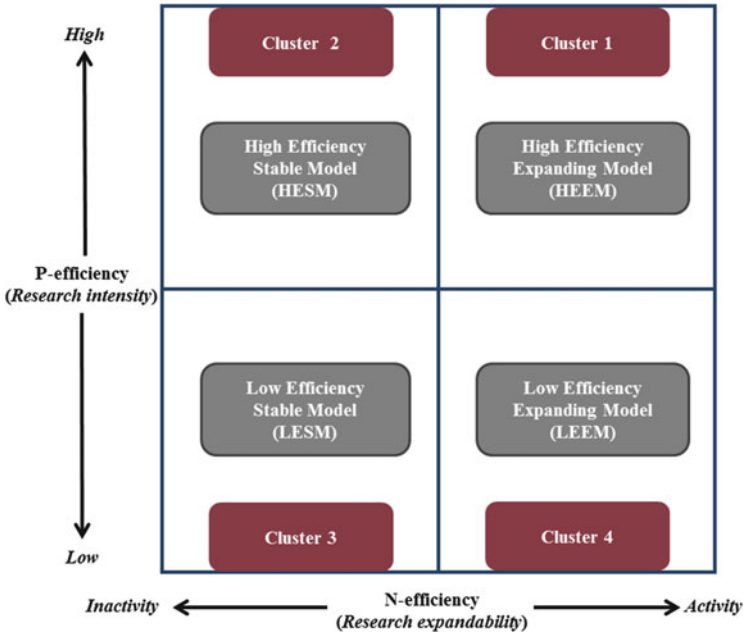

Fig. 7 Assessment model for research efficiency of university

Firstly, HEEM is growth oriented universities based on firm research foundation utilizing internal and external research environment effectively. Mainly graduate school focused large size universities and some small but specialized research universities belonged to this model.

HESM is stability oriented universities using available research resources effectively. Mainly education focused large size universities belonged to this model. If additional research capacity is added, they may seek to be HEEM.

LESM is universities with low internal research capacity without an investment availability for development. Thus, they need to secure research fund. Education focused small universities belonged to this model. They need to seek to be HESM by expanding research resources for improved efficiency.

LEEM may cause insolvency of universities due to an excessive investment of research resources despite a weak research environment, and may lead to damage of basis of overall research environment. Such universities need to secure soundness of research environment by appropriate investment of research resources in accordance with their research size. Thus, they need to endeavor to transfer to LESM.

This study aimed to verify the validity of models by comparative efficiency analysis, clustering of efficiency value and suggested assessment model for research efficiency of a university. The suggested model and empirical analysis process seem to be very reasonable in extracting research results for research efficiency of universities. The suggested model corresponds with the current research status of universities.

4.2 Limitations and Directions of Future Research

This study is an empirical study to verify the validity of efficiency model as the analysis from efficiency measurement, clustering and modeling with the reputation of universities. However, further verification of the validity of selected measures need to be made in future research.

While this study analyzed data for 2008, a more subtle model needs to be made with accumulated data. It is expected that the empirical analysis of this study would contribute to the improvement of basis of university researches, but it is also true that the affirmative link between competitiveness of research area and aspect of specialization was insufficient in arguing the importance of internal and external environmental foundation. We need to find more appropriate link to show the importance of internal and external environmental foundation.

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