

Measuring Distance Learning Performance with Data Envelopment Analysis

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In the modern society with changeable information technology learning and applications, students could acquire information application knowledge, which is not worse than those taught by teachers in classrooms, through the Internet, distance conference, and e-learning. Traditional instruction therefore is facing great challenges. When measuring the distance learning efficiency of universities with DEA, appropriate inputs and outputs should be selected for effectively evaluating the system performance of DMUs. From the DEA results, the distance learning efficiency of Xian Jiaotong University, Huazhong University of Science & Technology, Jiangnan University, Fujian Normal University, Beijing Normal University, Central South University, Chongqing University, Shanghai Jiao Tong University, and Central China Normal University do not reach 1, not achieving the optimum, while Beijing Language and Culture University achieve the optimum.

Keywords: Distance learning, DEA, educational efficiency.

INTRODUCTION

The rapid development of information technology has greatly changed the structure of industrial and occupational technology. Education-advanced countries like the USA, the UK, France, Germany, and Japan, have proposed curriculum reform, including providing curriculum for students' developmentally appropriate practice, stressing on life-oriented, flexible, and individualized courses, and cultivating the basic

competence, expecting to have students present the core capabilities to cope with the rapidly changing time.

Under the trend of global e-learning in 1999, the popularity of the Internet has the teaching and learning model through the Internet become a trend. The focus of education authority on e-learning is apparent. As a matter of fact, e-learning should be a major reform in modern educational learning systems.

After the open of educational service industry, foreign universities have changed the recruited students studying abroad to partially studying in Taiwan or proceeding web-based distance learning; meanwhile, subsidies for key universities in Mainland China are also enhanced for the increasing demands of talents. Apparently, higher education is considered as the key in national development and talent cultivation in both governments cross-strait. Besides, the frequent interaction has resulted in educational collaboration

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State of the literature

- The development of e-learning has digital materials become the major tool for computer-assisted instruction, which refers to the provision of digital materials with interactive functions for individual or individualized teaching environments.
- Such environments are computer-based with interactive functions that interaction becomes a critical function in e-learning materials.

Contribution of this paper to the literature

- The efficiency and the variable information acquired with DEA are classified in Table 2. One DMU, 10% of all DMUs, presents strong operation efficiency, with the efficiency 1, showing the optimal distance learning efficiency.
- Four DMUs, 40% of all, appear marginal inefficiency, with the efficiency between 0.9 and 1, revealing the distance learning being easily promoted.
- Five DMUs, 50% of all, show obvious inefficiency, with the efficiency less than 0.9, in which Central South University appears the lowest distance learning efficiency 0.74.

among the universities cross-strait. Besides, the increasing economic investment of Taiwan businesses in Mainland China also results in increasing Taiwanese students studying in higher educational institutes in China. In this case, the distance learning efficiency of universities in China is analyzed in this study.

LITERATURE REVIEW

Introduction of DEA

Farrell (1957) first proposed the concept of Data Envelopment Analysis (DEA) with mathematical planning model, which was acquired the efficient frontier, i.e. efficiency production function and then measured the technical efficiency through the differences between and the efficient frontier. Charnes et al. (1985) further expanded Farrell's efficiency measurement into the model for multiple inputs and outputs and named it as DEA. The DEA model proposed by above researchers are called CCR ratio model. The analyzed subjects of DEA are Decision Making Units (DMU); having selected the measured DMUs, the production resources are regarded as the inputs, and the produced products or objectives are the outputs. The efficiency evaluation with DEA appears between 0 and 1; the closer efficiency to 1 shows the better efficiency, while the closer efficient to 0 presents less efficiency. Such efficiencies are the relative

efficiency among DMUs that each of them could be directly compared the technical efficiency.

Different from Ratio Approach, the efficiency calculated with DEA is a relative efficiency, not an absolute one, that a single comparison index is acquired for avoiding the difficulty in comparisons. Different from Regression Analysis, DEA does not need to set production functions that it avoids the difficulties in model setting and is able to handle the efficiency with multiple inputs and outputs. Moreover, DEA, as a linear planning, could avoid subjective weights, as it is not necessary to artificially determine the relative importance of variables. Besides, multiple inputs and outputs from distinct DMUs could be simultaneously evaluated the efficiency, with which DMUs not achieving the efficiency are suggested to reduce inputs or increase outputs.

Non-profit businesses, such as educational systems, hospitals, courts, and governmental institutes, can hardly be evaluated the performance by profits or values decided by the market system. The advantages of Data Envelopment Analysis reveal on managers being able to set the inputs and outputs through various organizational objectives without presetting production functions and to establish a single comparison index for directly comparing the efficiency of DMUs. The evaluation results could also provide managers with operation objectives and directions that a lot more profit-making institutes start to evaluate the efficiency with Data Envelopment Analysis. Based on above advantages, DEA is utilized for evaluating the efficiency of educational sectors.

Analysis of DEA and evaluation of educational efficiency

Bessent et al. (1980) first measured educational efficiency with DEA by selecting 55 elementary schools as the DMUs to discuss the learning efficiency of the pupils. In Taiwan, Ku (1987) first applied CCR DEA to evaluating the efficiencies of 14 departments in a university, in which personnel expenses, current expenditure, and capital expenditure were regarded as the inputs and number of credits, number of SCI papers, and total amount acquired for defense industry programs as the outputs.

Beasley (1990) applied cone ratio DEA to evaluate the efficiency of physics and chemistry departments in 52 universities in the UK, in which current expenditure, costs of equipment, and research subsidies were regarded as the inputs and number of college students, postgraduates who are doing research, postgraduates on taught courses, research subsidies, and ranking of colleges and departments as the outputs. Zilla, et al. (1994) discussed 21 departments of Ben-Gurion University in 1988, in which current expenditure and

personnel expenses were regarded as the inputs and subsidies, number of academic publications, number of graduates, and number of credits as the outputs. Breu et al. (1994) evaluated the efficiency of top 25 National Universities and Liberal Arts Colleges announced by U.S. News and World Report in 1992, where average SAT score, percentage of doctorate lecturers, student-teacher ratio, expense for each student, and tuition fee of each student were considered as the inputs and graduation rate and freshman retention rate as the outputs.

Avkiran (2001) preceded DEA evaluation in 1995, aiming at the overall performance, academic performance, and recruitment performance of 36 Australian universities. The inputs of educational personnel and staff numbers and the outputs of total student number, professors' research outcomes, students' memory retention, students' progress, graduates who work full-time, number of overseas students, and number of non-overseas students were utilized. Chang (2010) applied BCC model to the long-term efficiency evaluation and Malmquist index of 50 public and private universities in the past decade and observed the changes of productivity, where enrollment of undergraduates, enrollment of graduates, number of staff, and other inputs (like current expenditure except personnel expenses) were regarded as the inputs and number of graduates, number of post-graduates, and research income as the outputs.

Distance learning

The development of e-learning has digital materials become the major tool for computer-assisted instruction, which refers to the provision of digital materials with interactive functions for individual or individualized teaching environments. Such environments are computer-based with interactive functions that interaction becomes a critical function in e-learning materials. The purpose of instruction with e-learning materials is to apply computers as the teaching tool to assisting students in learning activities and achieving individualized, repeated, or enormous teaching activities. In the learning process, the course design with digital materials allows the learning contents being displayed in order and the learners controlling the learning schedule and contents according to the learning situation.

Wang (2012) quoted the prediction of Bork (1978) that the major learning methods would be preceded through interactive learning with digital materials by 2000. Distance learning and web-based instruction are the trend in current information education. To achieve the distance learning performance, the following points are concluded for instructional reference.

The establishment of digital material team should have the team share and develop digital materials through creative brainstorming and enhance the integration of digital materials with information for various subjects.

Digital materials and resources should be organized and promoted for the enquiry systems in libraries, and VOD, CD servers, and web-based resources should be established according to the requirements of teachers.

Teaching innovation should allow the share from points to dimensions and learning development to lead the teachers applying information technology to creativities and assisting in teaching activities so as to make learning be more interesting and efficient.

Students' learning abilities should be enhanced by the assistant of information technology, with which students' learning interests could be promoted, multiple intelligence and knowledge could be inspired, and various key competence and information capabilities could be cultivated.

Subject web pages could be established by the learning and sharing of a team. Collaborative teamwork among subjects could also help establish the web pages.

The knowledge management platform could be established to include documentary management and instructional experiences for easy retrieval, acquisition, and application and progressed by the integration of teaching materials, online learning, experience passing down, and information mastering.

Favorable information learning situations and more information-integrated instruction could be practiced, as the convenience of information equipment and resources from the establishment of software and hardware in information environments allows teachers utilizing information medial for developing digital materials or applying computers as the assisted tools to the instructional activities.

Rich information teaching and learning resources allow students deepening, broadening, or reinforcing the academic learning through multi-dimensional instruction on the Internet and teaching platforms.

The acquisition of information and teaching materials could help promote knowledge and competence. Besides, teachers participating in information literacy workshops, investing in the development of student-oriented digital materials with innovative teaching could enhance learning channels and methods, enrich learning contents and performance, and promote overall educational quality.

RESEARCH DESIGN

DEA is applied to measuring the distance learning efficiency of universities in this study, in which the inputs and outputs are properly selected for efficiently evaluate the system performance of DEA. Fuzzy Delphi Method is used for screening inputs and outputs in order to combine expert opinions, decrease input costs, and avoid fuzziness in the process. Total 40 copies of questionnaires are distributed and 27 valid ones are

Table 1. Relative efficiencies of distance learning of universities

University	Overall efficiency	Pure technical efficiency	Scale efficiency
XianJiaotong University	0.93	0.92	0.94
Huazhong University of Science & Technology	0.82	0.83	0.1
Beijing Language and Culture University	1.00	1.00	1.00
Jiangnan University	0.88	0.86	0.85
Fujian Normal University	0.91	0.95	0.87
Beijing Normal University	0.98	0.95	0.94
Central South University	0.74	0.72	0.75
Chongqing University	0.86	0.84	0.83
Shanghai Jiao Tong University	0.90	0.91	0.90
Central China Normal University	0.80	0.79	0.81

Table 2. Relative efficiencies of universities with distance learning

Decision Making Unit (DMU)	Improvement for input		Improvement for output		Returns to scale
	Personnel expenses	Costs of equipment	Number of students	Student achievement	
Xian Jiaotong University	-1	0	-4	-2	IRS
Huazhong University of Science & Technology	-2	-3	-3	-2	IRS
Beijing Language and Culture University	0	0	0	0	CRS
Jiangnan University	-1	0	0	-5	IRS
Fujian Normal University	-3	0	-2	-3	IRS
Beijing Normal University	-1	0	-1	0	IRS
Central South University	-4	-2	-1	-1	IRS
Chongqing University	0	-1	0	-5	IRS
Shanghai Jiao Tong University	0	0	0	-1	IRS
Central China Normal University	-1	0	0	-2	IRS

Data source: Organized in this study.

retrieved, with the retrieval rate 68%. Fremont et al. (1970) indicated that public opinions with more than five participants could be the analysis reference. The interviewed experts in this study covering industries, officials, and academia reveal the representativeness because of the frequent interaction with the distance learning of universities.

After the computation of Fuzzy Delphi Method, the geometric mean is considered as the consensus of inputs and outputs. The median of the input/output evaluation results is used as the standard for selecting inputs and outputs to measure the distance learning performance of universities. Four input/output variables and 10 DMUs are selected in this study.

The variable data are the openly issued information. Definition of variables

Input variable

1. Personnel expenses refer to personnel expenses of universities.
2. Costs of equipment refer to the expenditure invested in distance learning (facilities, materials).

Output variable

1. Number of students indicates the number of recruited students.
2. Student achievement indicates the test results of students.

EFFICIENCY ANALYSIS OF DISTANCE LEARNING

Analysis of distance learning efficiency of universities

The efficiency evaluation with DEA could help understand the distance learning efficiency of universities. When the efficiency appears 1, the DMU achieves the relative efficiency; while the DMU reveals the relative inefficiency when the efficiency is less than 1. The empirical results, Table 1, showed that nine universities did not achieve the optimum, including Xian Jiaotong University, Huazhong University of Science & Technology, Jiangnan University, Fujian Normal University, Beijing Normal University, Central South University, Chongqing University, Shanghai Jiao Tong University, and Central China Normal University, while Beijing Language and Culture University achieved the optimal distance learning efficiency.

Analysis of Slack Variable

In regard to the analysis of returns to scale, Table 2, merely one university with distance learning presented the optimal constant returns to scale, while the rest nine universities appeared increasing returns to scale, showing the scale could be expanded to enhance the marginal return for the efficiency promotion.

Regarding Analysis of Slack Variable, improvements for universities with distance learning appearing abundant or insufficient inputs are shown in Table 2, which were suggested to reduce or increase inputs to achieve the operation efficiency.

CONCLUSION AND SUGGESTION

Kung (2009) and Ma (2010) divided DMUs into strong efficiency, marginal efficiency, marginal inefficiency, and obvious inefficiency. DMUs with strong efficiency (efficiency=1) and the slack variable being 0 show the great strength to overpass inefficiency that they should be able to retain the efficiency unless there are major changes in inputs and outputs. DMUs with marginal efficiency (efficiency=1) but at least one slack variable not being 0 could reduce the efficiency down to 1 by increasing inputs or reducing outputs. DMUs with marginal inefficiency ($0.9 < \text{efficiency} < 1$) could easily enhance the efficiency up to 1. The ones with the efficiency less than 0.9, as obvious inefficiency, are considered difficult to become efficient in a short period; particularly, the ones with the efficient less than 0.75 would remain inefficient unless there are major changes in inputs and outputs.

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all DMUs, presents strong operation efficiency, with the efficiency 1, showing the optimal distance learning efficiency. Four DMUs, 40% of all, appear marginal inefficiency, with the efficiency between 0.9 and 1, revealing the distance learning being easily promoted. Five DMUs, 50% of all, show obvious inefficiency, with the efficiency less than 0.9, in which Central South University appears the lowest distance learning efficiency 0.74.

From the DEA results, there are more than 0.36 billion mobile surfers in China that electronic could reduce 80% textbook production costs. Furthermore, Beijing Language and Culture University is widely appraised the web-based distance education that it has been awarded "Top Ten Web-based Educational College", "Web-based educational institutes appraised by million readers", and "The most trustable distance education brand". In such a mobile network, Web College of Beijing Language and Culture University utilizes the rich experiences in curriculum design and platform development for modern distance learning and teaching management platforms suitable for higher education and enterprises. Moreover, the online learning platform (<http://eclass.beiwaibest.com/>) developed for individual learners provides the members with the services of online courses selection, online ordering, online payment, and online learning so that learners around the world could enjoy the high-quality language learning resources of Beijing Language and Culture University. Beijing Language and Culture University has actively promoted fair education, reasonably allocated educational resources, tended to agricultural, remote, poor, and ethnical areas, supported special education, enhanced the funds for students with economic difficulties, and promoted agricultural and industrial children equally receiving education so that each child becomes talented. Being a "Foreign language expert of web-based education in China", the online learning platform of Beijing Language and Culture University has broken the wall of higher education and made continuous education and lifelong education become possible for equal educational resources. Anyone could log in the learning platform of Beijing Language and Culture University listening to the experts' lectures and learning knowledge in the system.

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