CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

A MEASUREMENT OF THE RESOURCE UTILIZATION EFFICIENCY OF UNIVERSITY LIBRARIES IN TAIPEI

TSER-YIETH CHEN

DISCUSSION PAPER SERIES No.9701

January 1997

財團法人 中華經濟研究院

CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH
75 Chang-Hsing St., Taipei, Taiwan, 106
Republic of China
TEL: 886-2-735-6006
FAX: 886-2-735-6035

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A Measurement of the Resource Utilization Efficiency of University Libraries in Taipei

by

Tser-yieth Chen

Associate Research Fellow
Chung-Hua Institution for Economic Research

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Chung-Hua Institution for Economic Research

75 Chang-Hsing St., Taipei, Taiwan 106

Republic of China

TSER-YIETH CHEN*

A Measurement of the Resource Utilization Efficiency of University Libraries in Taipei

Abstract

This paper employs data envelopment analysis (DEA) to measure the relative resource utilization efficiency of 23 university libraries in Taipei City and County. The most notable feature of this paper is that it uses a single input/output measure to characterize efficiency/performance. We calculate the overall efficiency score, as well as the technical and scale efficiency scores of each university library. The estimated results show that 11 university libraries are relatively efficient. The results also show that nine out of these 11 have a relatively good academic research function. Only two of them are attributed lower research capabilities. We also rated the top three libraries which enjoy the highest levels of efficiency in the sample. This shows that the resource utilization of these university libraries is functioning well. Finally, we find that the inefficient libraries manage their acquisition expenditures and book circulation poorly.

Keywords: Data envelopment analysis, relative efficiency, performance measurement, university library

*Associate Research Fellow, the Center for Fnergy and Envirenmental Stndies, Chung-Hua Institution for Economic Research, Taipei, R.O.C..

I. Introduction

At all levels of the education sector, one hear that universities can and should be held accountable for the services they provide. In the 1980s, a push for accountability was undertaken in universities in the United States and all libraries faced the task of allocating scarce resources among competing ends. University libraries have been concerned with efficiency and current tight economic conditions have further highlighted the importance of that concern. Taiwan's universities also have faced the accountability issue in the 1990s and administrators have brought about some revolutionary changes. In addition to being accountable for the education function, libraries, like other nonprofit institutions, must compete for resources at a time when resource scarcity dominates. A university library may be viewed as an enterprise in which the professional staff provides the operating conditions for converting quantifiable resources (inputs) into pupil learning and teachers' research (outputs). That is to say, budget constraints ensure that there is only so much money available, and whether or not there is a price tag attached we need to choose among competing options. From time to time there have been efforts to improve efficiency in university libraries. The efficiency of university libraries is a critical issue in budgeting. The purpose of this paper is to measure the resource utilization efficiency of university libraries.

In this paper, university library efficiency refers to resource utilization efficiency, rather than an evaluation of effectiveness. It indicates that the job has been done right, but in no way ensures that the right job has been done. Because the effectiveness of a university library involves the objective achievement of an individual university, there exists no independent measure of "ideal" or a standard indicator to measure the objectives of the university. In most cases, university libraries offer similar services, but there is no absolute standard. Rather, it is a relative concept that invites comparison, so

we view efficiency relatively. A library is efficient when it is able to show that particular activities have a greater potential payoff than do other libraries.

We employ a data envelopment analysis (DEA) model to calculate the overall, efficiency and measure the technical and scale efficiencies of 23 university and college libraries in this paper. We take the role of resource manager and recognize that resources are scarce and we cannot afford to waste them. We want university libraries to be productive so that they can provide better service in light of constraints and attract more readers. Given the circumstances, we argue that the DEA model is a mathematical model designed especially for application to nonprofit institutions like the university library. There are three reasons: (i) The DEA model is able to derive a single aggregate score which indicates the performance status of each library relative to a designated group of peers. (ii) The DEA model is capable of identifying any perceived slacks in input used or output produced, and provide insight on possibilities for increasing outputs and/or conserving inputs in order for an inefficient library to become efficient (productive). (iii) The DEA model can also maintain equity in performance assessment to handle noncommensurate multiple outputs and inputs using a mathematical programming method to generate a set of weights to each input/output. In the following sections, we first review the related literature, then discuss the proposed DEA model and input/output items. Section four is the empirical results of 23 university and college libraries in the Taipei area. The fifth section is the concluding remarks.

II. Literature Review

The evaluation of university library performance/efficiency has been approached from a variety of dimensions. Traditional approaches have generally been concerned with the input base, i.e., personnel, book collection, seating capacity, etc. The Standards for University Libraries (1979) and

Management Review and Analysis Program (Orr, 1973) are two well-known examples which indicate that higher resource installation promises a higher performance level. Brophy (1986) argues that the size of the book collection is normally positively correlated to the length of time since library installation, but that it obviously does not represent the extent of book circulation.

Another line of research uses the output measure as the performance indicator. There are two main reasons for using the output measures. The first is the shrinkage of school budgets for libraries which came about due to the global economic depression in the 1980s. The second is high competition within universities, where the university's library must increase their services to satisfy the demands of students. Kantor (1984) suggests that book circulation, data reference frequency, and book availability are the basic measures for evaluating the performance of university libraries. Van House (1990) posits 15 output indicators which can be grouped into four output categories: book utilization, data availability, information service, and overall satisfaction for measuring the performance of academic libraries. Recent empirical studies also utilize this tactic, including Kelley (1990), Wittkopf and Cruse (1991), and Jurow (1993). Shaughnessy (1993) points out that utilizing output measures may overlook the input costs and the quality factor. He argues that we need to include both input factors and output factors to measure library performance. Guyonneau (1993) also applies an input/output ratio to measure university library performance. Easun (1994) applied the data envelopment analysis method to evaluate the performance of junior-high school libraries in California. As far as this author knows, it is the first paper which uses the DEA method to evaluate the performance of school libraries. This paper then extends the DEA approach to measure technical/scale efficiency and apply it to the university library field.

Most of the limited research on performance/efficiency evaluation of libraries has conducted a variant of the case study or undertaken ratio analysis for parallel comparison among several libraries using a number of "performance indicators." The main weakness of ratio analysis is that there is a lack of agreement on the relative importance of various types of inputs on outputs. When we adopt multiple measures (i.e., ratio analysis), we find that

some libraries are better than average by certain measures, but poorer than average by others. The most notable feature of this paper is that it uses a single input/output measure to characterize efficiency/performance. We then view efficiency/performance in terms of relative resource utilization efficiency which, simply put, is: how efficiently is a given university library performing relative to other similar libraries.

III. Data Envelopment Analysis

In this section, we propose data envelopment analysis to evaluate relative efficiency for 23 libraries. The DEA method was first described by Charnes, Cooper and Rhodes (1978) who employed a mathematical planning model (CCR model) to measure the efficiency frontier based on the concept of Pareto optimum. Then Banker, Charnes and Cooper (1984) developed a revised model (BCC model) to measure technical efficiency and scale efficiency. The basic idea of DEA is to identify the most efficient decision-making unit (DMU) among all DMUs. The most efficient DMU is called a Pareto-optimal unit and is considered the standard for comparison of all other DMUs. The Pareto-optimal unit is the one such that any change that makes some people better off makes others worse off (Gould and Ferguson, 1980). Conversely, a unit is Pareto nonoptimal if some people can be made better off without harming anyone else. The magnitude of the performance score of Pareto nonoptimality is calculated by dividing the Pareto-nonoptimal DMU into the Pareto-optimal DMU. Therefore, the DEA score is a relative number rather than absolute.

The idea of calculating DEA scores can be formulated as a fractional linear programming problem. We denote Y_{kj} as the j-th output of the k-th DMU and X_{ki} as the i-th input of the k-th DMU. If a DMU employs p inputs to produce q outputs, the score of k-th DMU, E_k, is a solution from the

fractional linear programming problem (CCR model):

$$\underset{U_j V_i}{Max} \; E_k = \frac{\sum_{j=1}^{q} U_j Y_{kj}}{\sum_{i=1}^{p} V_i X_{ki}} \qquad i = 1.2.....p \qquad j = 1.2.....q \qquad r = 1.2.....K.....R$$

$$s.t. \qquad \frac{\sum_{j=1}^{q} U_j Y_{rj}}{\sum_{i=1}^{p} V_i X_{ri}} \le 1 \qquad U_j, V_i \ge 0$$

where U_j and V_i give the slacks in the j-th output and the i-th input, respectively. We have generalized the usual input/output ratio measure of efficiency for a given library with fractional constraints. In the case of libraries, the efficiency of a particular library is calculated by finding the ratio of a weighted sum of outputs to a weighted sum of inputs. The BCC model is the revised version of the CCR model. The former model can be reformulated by adding $\sum_{j=1}^{n} \lambda_j = 1$ to the problem, which provides valuable information about the costs-benefits (BCC model):

$$Min \;\; TE = \theta - \varepsilon\left(\sum_{j=1}^{p} S_{ki}^{-} + \sum_{j=1}^{q} S_{kj}^{+}\right)$$

$$\text{s.t.} \;\; \sum_{r=1}^{T} \lambda_r \chi_{ri} - \theta \chi_{ki} + S_{ki}^{-} = 0$$

$$\sum_{r=1}^{T} \lambda_r Y_{rj} - S_{kj}^{+} = Y_{kj}$$

$$\sum_{r=1}^{T} \lambda_r = 1 \qquad , \;\; \lambda_r \ge 0$$

Where O is the efficiency score and ε is a nonarchimedean quantity the value of which is very minute. Note that we can calculate the (pure) technical efficiency score from the BCC model, then the scale efficiency score can be derived by overall efficiency and technical efficiency scores because the overall efficiency score is equal to the power of (pure) technical efficiency

and scale efficiency score (Fare et al., 1985). Furthermore, we develop a three-step procedure to supply a practical application to the theoretical DEA model:

1. Identify the output/input items

The first step in applying the DEA model is to identify the set of input factors and output measures to be included in the analysis. Measuring Academic Library Performance (MALP), a comprehensive manual of performance evaluation, is recommended by the American Library Association (ALA). The MALP manual provides multiple output measures for university library performance evaluation. The evaluation in this paper is based on the MALP manual published by ALA combined with the personal judgment of the evaluators. Based on the manual, the output measure is conducted using the following items: (1) reader visits or attendance, (2) book circulation, (3) reference transaction and on-line search, and (4) reader satisfaction. The above four items are identical to the four categories listed in the MALP manual (library use, materials use, information service, and overall satisfaction). In some cases, the appropriate output items can be obtained from experienced library administrators. Therefore, after discussion with library administrators, we added another two output items: (5) annual service hours and (6) interlending service. It is noted that the interlending service can reflect the provision of an academic function by the university library, for a higher frequency of interlending service represents greater support of the library to academic research. Annual service hours represents the time the library is available for use; it is a good indicator of the personnel and equipment utilization.

The input measures are based on the items listed in the Standard of University Libraries provided by the American University Library Association. Following the Standards for University Libraries, our evaluation selects the following five input measures: (1) library staff, (2) book collection, (3) book acquisition expenditure, (4) area of library space, and (5) seating capacity. The data are selected from the survey of Taiwan's Library Investigation

conducted by the National Central Library (NCL), and the time period is 1995.

Note that we utilized IDEAS (Integrated Data Envelopment Analysis System) software to run the above DEA model. It is also noted that the area of library space and the seating capacity are highly correlated in our previous experience. We need to exclude one of them to avoid a multicollinearity problem in the DEA model. Book collection and book acquisition expenditure are the same. The results of correlation analysis support the high correlation phenomenon between: (i) area of library space and seating capacity, with a correlation coefficient of 0.9293, (ii) book collection and book acquisition expenditure, with a correlation coefficient of 0.9025.

2. Isotonicity Test

The next step involves a determination of the relationship between inputs and outputs. The DEA model requires definitions of the inputs and outputs so that when the inputs are added the outputs will increase. We employ correlation analysis to test the isotonicity, the positive direction of the relationships between inputs and outputs. According to the results of inter-correlation analysis, we easily see that the correlation coefficient between outputs and inputs are all positive and the isotonicity test is passed. The results are shown in Table 1.

3. Determine output and input items

We utilize a backward elimination method to determine the output and input items. The backward elimination method is developed from the concept of stepwise regression and was introduced by Sengupta (1988). The procedure is as follows: First, we conduct a DEA procedure on designated output and input items and calculate the efficiency score and slack coefficients between nonzero slacks and efficiency scores. Second, we delete the minimum figure corresponding to input/output items. Third, we repeat the above procedure until we accept the desired input/output items. Basically,

Table 1. Correlation Matrix Between Inputs And Outputs

Inputs \ Outputs	Reader Visits	Book Circulation	Reference and On-line Research	Annual Service Hours	Reader Satisfaction	Interlending Service
Library Staff	0.8592	0.8774	0.8879	0.0602	0.3219	0.4967
Book Acquisition Expenditure	0.9132	0.8890	0.7436	0.0290	0.6253	0.6242
Book Collection	0.8910	0.8809	0.8938	0.0076	0.3608	0.5093
Area of Library Space	0.8863	0.8517	0.8337	0.2416	0.4999	0.6918
Seating Capacity	0.8882	0.8907	0.7783	0.3181	0.4577	0.6716

the desired number of input and output items is needed because if we add one more input or output to the DEA model, it will decrease the discriminatory power of the efficiency score (Boussofiane et al., 1991), and increasing the number of DMUs will create a 1.0000 efficiency score. We adopt the rule of discrimination suggested by Golany and Roll (1989), that is, that the power of the number of items of output and input must be less than the number of DMU units. In our case we have 23 DMUs and we need four inputs and five outputs at most, or vice versa.

Based on the above procedures, the DEA model was performed with the following four output variables: reader visits, book circulation, reference transaction and on-line search, and interlending service. The input variables consisted of three variables, that is, library staff, book acquisition expenditure, and area of library space. We choose only seven input/output variables rather than nine as discussed in the rule of discrimination. When we included nine variables, we found that 16 of 23 DMUs had a 1.0000 efficiency score. Too many efficient DMUs obviously reduces the discrimination capability of the performance evaluation results. Therefore, we excluded two variables to improve our estimated results.

IV. Empirical Results

For the inputs and outputs described above, we calculated the efficiency rating E_k for 23 university libraries in Taipei City and County. The empirical results of the DEA model serve as a valuable diagnostic tool, the diagnostic power of which can be observed first with reference to the efficiency score of each DMU in the library system, and second, the slack analysis provides direction for managerial auditing.

1. Efficiency Score Analysis

The efficiency score analysis shows that 11 university libraries are relatively efficient, and their efficiency scores are all equal to 1.0000. This shows that the resource utilization of these university libraries is functioning well. In order to interpret the contents of efficiency, more discrimination among the 11 efficient libraries was undertaken. We modified the method proposed by Charnes, Cooper and Thrall (1991) and used the frequency in the reference set to discriminate among them. The frequency with which a DMU shows up in the reference set of other DMUs represents the extent of robustness of the DMU compared with other efficient DMUs. The higher the frequency, the more robust it is. Table 2 shows that the 11 efficient libraries can be categorized into three groups: (1) Marine & Oceanic University, Yang-ming University, and Ming-chuan Management College can be placed in the highly robust group. (2) Taiwan University, Normal University, Taipei Normal College, and Taiwan Institute of Technology are in the middle robust group. (3) Cheng-chi University, Chung-shing University, Shih-chien Design College, and Fu-zeng University are classified in the low robustness group. It must be noted that Fu-zeng University Library can further be categorized into a fourth group (little robustness), because Fu-zeng University

Table 2. Efficiency Scores of 23 University Libraries

Name of University	ID	Scores	Reference Set	Frequency of Showing in the Reference Set
Taiwan Univ.	1	1.0000	1.7.11.22	5
Cheng-chih Univ.	2	1.0000	2.7.8	2
Normal Univ.	3	1.0000	1.3.7.11	6
Chung-hsing Univ.	4	1.0000	4.9.22	2
Marine & Oceanic Univ.	7	1.0000	1.3.7.11	14
Taiwan Inst. of Technology	8	1.0000	8.9	8
Yang-ming Univ.	9	1.0000	8.9	10
Taiwan College of Education	11	1.0000	1.7.11.22	8
Fu-zeng Univ.	15	1.0000	7.9.15	1
Ming-chuan Mgmt. College	23	1.0000	8.9.22	16
Shih-chien Design College	24	1.0000	7.22.23	3
Tam-kang Univ.	16	0.9518	4.9.22	0
Taipei Normal College	12	0.9268	7.8.22.23	0
Taipei Medical College	21	0.8369	9.22	0
Univ. of Chinese Culture	17	0.7725	3.7.11.22	0
Open Univ.	5	0.6316	9.22	0
Taipei Inst. of Technology	13	0.6057	7.8.22.23	0
Ta-tung Inst. of Technology	18	0.5620	7.9.22	0
Soochow Univ.	14	0.5458	3.7.11.22	0
World College of Journalism	20	0.4885	1.3.11.22	0
Univ. of Overseas Chinese Students	6	0.4227	3.7.11.22	0
Taiwan College of Arts	10	0.4098	2.7.8	0
Hua-fan Inst. of Technology	19	0.3253	8.9.22	0
Libraries with 1.0000 Scores	-	11	Total	75

Library is not found in another reference set of libraries. This implies this library is not very similar to the other ten efficient libraries and has its own peculiarity and specialty.

The 12 inefficient libraries all had efficiency scores less than 1.0000. The figure shows that inefficient libraries can improve to efficient libraries by decreasing resource inputs and increasing outputs. For example, the

efficiency score of University of Chinese Culture Library is 0.7725; it can be interpreted that this library has attained 77% efficiency. That is to say, the University of Chinese Culture Library only reaches 77% of the level of outputs of efficient libraries with the same level of inputs. Moreover, we divided the 12 inefficient libraries into two subgroups using the median of efficient scores to isolate the worst libraries among the inefficient ones.

Furthermore, we can divide the 23 libraries into two groups according to another dimension, that is, relatively high academic research function libraries and libraries with a relatively low research function when we report the results of efficiency score analysis. Because there are quite a few differences in academic research support among university libraries based on the specific objectives of the university, we need to determine the efforts in research academic support taken by university libraries. We have chosen two indicators, the volume of periodicals and interlending service, to determine this. The volume of periodicals reflects the resources for doing academic research and the interlending service shows academic research activities. The results show that nine of eleven efficient university libraries have a good academic research function. Only Ming-chuan Management College and Shih-chien Design College are attributed lower research capabilities. The detailed results are shown in Table 3.

2. Slack Analysis

For the resource manager, the next step is of interest in estimating how much the outputs could be increased and/or the magnitude of inputs that could be conserved by inefficient libraries. This means additional decreases in specific inputs could be achieved for a library to operate as well as the most efficient libraries, and increases in output could be reached at lowered levels of resource inputs. Table 4 illustrates the results of slack analysis for 12 inefficient libraries. For each inefficient library, we further break down the inefficiency in terms of specific outputs and inputs. The results show that the average potential increase in annual reader visits is 19,300, representing a 19% improvement. The average potential increment of book circulation is

Table 3. Classification of University Libraries

Items		Relatively High Academic Research Function	Relatively Low Academic Research Function
Efficient Libraries	High Robustness	Marine & Oceanic Univ. Yang-ming Univ.	Ming-chuan Management College
	Middle Robustness	Taiwan Inst. of Technology Taiwan College of Educatn. Normal Univ. Taiwan Univ.	
	Low Robustness	Cheng-chih Univ. Chung-hsing Univ. Fu-zeng Univ.	Shih-chien Design College
Inefficient Libraries	Beyond Median	Tam-kang Univ. Univ. of Chinese Culture	Taipei Normal College Taipei Medical College Open Univ. Taipei Inst. of Technology
	Below Median	Soochow Univ.	Ta-tung Inst. of Technology World College of Journalism Univ. of Overseas Chinese Students. Taiwan College of Arts Hua-fan Inst. Of Technology

24,300 volumes, or 28% improvement. As to the reference transaction and on-line search and interlending service, the average potential increases are 4,400 (5%) and 580 (33%), respectively. The average potential reduction in library staff, book acquisition expenditure, and area of library space are also listed in Table 4.

We also selected a number of nonzero slacks for each output/input to cross-check the above results. Nonzero slack identifies the marginal contribution in efficiency score with additional specific input amounts. We find that the book acquisition expenditure and book circulation factor enjoy the largest number (seven) of cases of nonzero slack. This implies that we can effectively promote resource utilization efficiency in inefficient libraries

Table 4. Amount of Improvement for Each Measurement of Inefficient University Libraries

Items / Libraries	Inputs			Outputs			
	Library Staff (person)	Book Acquisition Expenditure (million)	Area of Library Space (thousand m^2)	Reader Visits (thousand)	Book Circulation (thousand)	Reference Search (thousand)	Interlending Service (thousand)
Tam-kang Univ.	4 (43.8)	5 (64.7)	2 (43.8)	17 (23.2)	64 (86.4)	0 (0)	0 (0)
Taipei Normal College	1 (9.3)	0.2 (9.3)	0.2 (13.0)	0 (0)	0 (0)	7 (50.7)	0 (0)
Taipei Medical College	2 (26.4)	1 (24.0)	0.3 (16.5)	11 (17.1)	49 (74.2)	0 (0)	0 (0)
Univ. of Chinese Culture	7 (22.6)	2 (22.8)	4 (40.3)	0 (0)	7 (2.6)	0 (0)	2.6 (37.7)
Open Univ.	6 (54.5)	3 (76.2)	0.4 (37.0)	43 (95.6)	54 (94.7)	0 (0)	0.1 (9.5)
Taipei Inst. of Technology	6 (39.4)	2 (39.4)	5 (65.4)	0 (0)	0 (0)	20 (80.2)	2.2 (77.1)
Ta-tung Inst. of Technology	4 (43.8)	5 (64.7)	2 (43.8)	17 (23.2)	64 (86.4)	0 (0)	0 (0)
Soochow Univ.	20 (45.4)	5 (45.4)	5 (51.2)	0 (0)	110 (42.1)	0 (0)	0 (0)
World College of Journalism	7 (51.1)	3 (64.2)	2 (51.0)	23 (43.4)	0 (0)	0 (0)	02 (88.7)
Univ. of Overseas Chinese Students	2 (57.7)	0.5 (58.0)	4 (89.2)	0 (0)	7 (44.1)	0 (0)	0.2 (95.9)
Taiwan College of Arts	5 (59.0)	21 (89.3)	5 (78.0)	0 (0)	0 (0)	0 (0)	1.6 (93.6)
Hua-fan Inst. of Technology	7 (74.7)	4 (90.2)	0.7 (66.7)	0 (0)	0.2 (0.9)	0 (0)	0 (0)
Average (%)	43.9	48.9	46.4	19.6	28.7	5.4	33.5

Notes: The figures in parentheses are the percent of potential improvement.

by better handling a library's book acquisition expenditure efficiency and enlarging the book circulation function. We suggest that these libraries should address these two areas in order to enhance their performance.

More detailed insights can be found from slack analysis at the individual library level. Here we also take University of Chinese Culture Library as an example. Clearly, this library should additionally be able to improve the book circulation and interlending service to that of efficient libraries by 3% and 38%, respectively. The University of Chinese Culture Library should be able to reach its current output level even if one of the inputs was cut to 77%

(library staff), 77% (book acquisition expenditure), or 60% (area of library space) of their existing level. The result shows the existence of a great amount of slack for this library and the need to utilize resources more efficiently.

3. Technical and Scale Efficiency Analysis

As seen from Table 5, there are 11 university libraries with a unity overall efficiency score. The remaining 12 libraries are inefficient. Table 5

Table 5 Estimated Results of Technical Efficiency and Scale Efficiency Scores

Name of University	ID	Overall Efficiency Score	Technical Efficiency Score	Scale Efficiency Score
Tam-kang Univ	16	0.9518	1.0000	0.9518
Taipei Normal College	12	0.9268	1.0000	0.9268
Taipei Medical College	21	0.8369	1.0000	0.8369
Univ. of Chinese Culture	17	0.7725	0.9755	0.7919
Open Univ.	5	0.6316	1.0000	0.6316
Taipei Inst. of Technology	13	0.6057	0.6658	0.9097
Ta-tung Inst. of Technology	18	0.5620	0.7867	0.7144
Soochow Univ.	14	0.5458	0.6250	0.8733
World College of Journalism	20	0.4885	0.7139	0.6843
Univ. of Overseas Chinese Students	6	0.4227	0.6196	0.6822
Taiwan College of Arts	10	0.4098	0.6067	0.6755
Hua-fan Inst. of Technology	19	0.3253	0.4857	0.6698

also shows the sources of inefficiency among the 12 libraries. Seven of them show that the score of technical efficiency is higher than the scale efficiency score. This implies that the inefficiency of resource utilization of these seven libraries will be roughly attributed to the scale factor, rather than the technical factor. The result indicates that we need to reexamine the scale of investment among these seven libraries. Conversely, five libraries are

judged to be technically inefficient because they have a higher scale efficiency score. For example, Taipei Institute of Technology has a magnitude 0.6057 of overall efficiency and breaks down into technical efficiency score (0.6658) and scale efficiency (0.9097). The lower technical efficiency score implies that technical inefficiency promises to be the major area where it can build up its overall inefficiency.

V. Concluding Remarks

We have shown that university libraries can be investigated in terms of their relative efficiency scores and illustrated the insights available from slack analysis. In this paper, DEA is clearly a powerful evaluation tool that mathematically estimates the maximum possible aggregate efficiency score by integrating the combination relationships of inputs and outputs of 23 nonprofit comparative libraries. The estimated results show that 11 university libraries are relatively efficient, and 9 out of 11 efficient university libraries have a good academic research function. Only Ming-chuan Management College and Shih-chien Design College are attributed lower research capabilities. Among them, Marine & Oceanic University, Yang-ming University and Ming-chuan Management College are the top three libraries and greatly surpass the robustness of the inefficient libraries.

Of the 12 inefficient libraries, DEA estimated results provide a diagnosis as to how to improve potential efficiency by better utilization of inputs or more production of outputs. This shows that we can effectively improve the resource utilization efficiency of the 12 inefficient libraries by better operation of book acquisition expenditure and expanding the volume of book circulation. Moreover, we further find that 7 university libraries have obvious scale inefficiencies and 5 libraries have technical inefficiencies and point out the possible directions for improvement.

Basically, the perspectives of this evaluation are those of the

administrator of the libraries (resource manager viewpoint) and of tuition-payers (resource user viewpoint). The perspective of other constituencies is involved in relevant input/output measures, and tends to reveal the goals that those conducting the analysis consider important. Any important missing inputs/outputs will obviously bias the result of the DEA model. In fact, it is unlikely that there is worldwide agreement about what constitutes the important inputs/outputs of a university library. We used measures given in the book "Measuring Academic Library Performance" and adjusted them to fit our practical application. We finally decided upon four output measures and three input items (reader visits, book circulation, reference transaction and on-line search, and interlending service (output measures), and library staff, book acquisition expenditure, and area of library space (input items)). However, it is very important when conducting DEA to resist the temptation to present results as an objective declaration of performance, irrespective of the chosen input/output measures.

There are two major problems we encountered in our study: (1) Output measures do not include quality-type indicators, e.g., service quality and equipment quality, due to limited data. (2) It is difficult to communicate our results to relevant library' managers because it is a complicated quantitative process. We expect that these problems will become less severe with increased experience. Moreover, because university library evaluation in Taiwan requires on-site visits, most conclusions and suggestions are qualitative and generated by the evaluator. Further research is needed on the process for combining qualitative on-site visits and the quantitative method proposed in this paper. If such a method could be found, not only would manpower and budgets be saved, but a more objective result could be developed. It would be a worthwhile task to undertake this effort in the near future.

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