Application of DEA on Teaching Resource Inputs and Learning Performance

Bernard Montoneri  
Department of English Language, Literature and Linguistics  
Providence University, Taiwan  
bmon@pu.edu.tw

Chia-Chi Lee  
Department of Accounting Information  
National Taipei College of Business, Taiwan  
clee.vera@msa.hinet.net

Tyrone T. Lin  
Department of International Business  
National Dong Hwa University, Taiwan  
tjlin@mail.ndhu.edu.tw

Shio-Ling Huang  
Department of International Business  
National Dong Hwa University, Taiwan  
sihuang@mail.ndhu.edu.tw

This paper aims at exploring the quantitative learning performance of English conversation for freshmen in a university of Taiwan by applying data envelopment analysis (DEA). The students following a certain language learning program are chosen as the research object. This paper designs a learning performance mechanism to identify the main input indicators (the richness of course content, the diversity of accessed multiple learning channels) having a significant impact on the students’ learning performance. We focus firstly, under the same input resources, on the gap between the actual output performance and the target output performance in order to clarify the amount of improvement necessary to reach the optimal performance of outputs. We identify the decision making units (DMUs) with the best performance and those needing some adjustments. This study provides suggestions to teachers and students about how to make a better use of limited teaching and learning resources. The research result acquired by applying DEA can further indicate whether existing teaching scale is in optimal size, and whether students’ learning efforts and teachers’ teaching efforts will reach the expected performance.

Keywords: Data enveloped analysis (DEA), learning performance, teaching resources

Introduction

Over the last decade, the number of colleges and universities in Taiwan has increased by 69, from 78 in 1997 to 147 in 2006. However, the ratio of spending by the government in education has decreased from 5.37% 1996 to 4.39% in 2005 (Hsu, 2008). According to the Ministry of Interior (2010), Taiwan has the lowest birth rate in the world: 0.83. As a result, the number of students is decreasing dramatically, even though the acceptance rate for colleges and universities has reached 90.93% in 2006 (Hsu, 2008). This situation will inevitably pose the question of the survival of many educational institutions which are already facing financial plight. Higher education has become increasingly competitive and universities must enhance their reputation to ensure their future. In recent years, the Ministry of Education, in order to allocate more efficiently limited education resources and to control the quality of schools, is undertaking a performance evaluation for every college and university in Taiwan. Primary, elementary, junior and high school are not concerned by this performance evaluation for the time being. Higher Education institutions, especially the private ones, hope to obtain an
excellent evaluation and to receive more financial support from the Ministry of Education in order to avoid low student enrollment, high graduate unemployment, credential inflation, and even university closure.

The Ministry of Education promotes an Excellent Teaching Project. This program aims at encouraging Higher Education institutions to improve teaching effectiveness. Universities which obtain this project generally set up an Excellent Teaching Center and define some indicators of teaching performance for teachers to follow. The indicators selected for this study satisfy not only teaching effectiveness at the level of English conversation courses or any other specific subject, but at the level of the Excellent Teaching Centers of Higher Education institutions as well as at the level of the Ministry of Education. The design of teaching performance indicators follows this bottom-up program in order to enforce the competitiveness of the country. The results of the performance evaluation via the selected indicators can serve as a reference for the Ministry of Education to formulate educational policies.

Among the many evaluated items by the Ministry, one of the most fundamental is students’ learning performance. The quality of students learning not only has an influence on the long-term relationship to a country’s future growth and competitiveness, but also on the short-term impact, on the employment rate of graduate students, or even whether the school can or cannot attract enough freshmen. The evaluation of learning performance is also used for the organizations possessing human resources as their major assets. In a fierce competitive market, employees’ working performance and learning performance can be as fatal as in other industries and fields.

This paper aims at exploring the quantitative learning performance of English conversation for freshmen in a university of Taiwan by applying data envelopment analysis (DEA). Compared to other popular methods for performance evaluation such as stochastic frontier analysis (SFA) or structural equation modeling (SEM), data envelopment analysis (DEA) is appealing to scholars since it can assess the technical efficiency of decision making units (DMUs) with multiple inputs and multiple outputs using only information on input and output quantities (Fu & Huang, 2009).

As mentioned in the literature review, the DEA evaluation method has been widely applied in various industries and is proved to be quite reliable. It has also been applied to assess the efficiency of higher education institutions, but there is little application of DEA on language learning performance, notably concerning non-native students of English. This evaluation approach of learning performance can be employed to other branches of learning, even to corporate employee training.

The remainder of the paper is organized as follows: the literature review presents a few academic researches in relation with our paper. The methodology and chosen key items explain the DEA method and the important dimensions discussed in the paper. The following section presents the obtained primary numerical results based on the empirical data. The final paragraph draws the conclusions and implications.

Literature review

Many scholars have conducted research on what makes an excellent teacher (Bain, 2004; Fink, 2003). Wolf, Bender, Beitz, Wieland, & Vito (2004) described the strengths (being a knowledgeable and strategic teacher, creating a positive learning environment, demonstrating professionalism, demonstrating positive personal traits, and displaying scholarly traits) and weaknesses (providing poor delivery of course content, acting disorganized, being inaccessible, and displaying weak teaching skill) in faculty teaching performance as reported by undergraduate and graduate nursing students. McGowan and Graham (2009) studied the factors contributing to improved teaching at Brigham Young University (BYU), a private church-sponsored university. They determined that the top four factors leading to improvement were active/practical learning (providing real-world experiences and in-class discussions), teacher/student interactions (knowing each student personally), clear expectations/learning outcomes (having high and clear expectations for the students), and faculty preparation.

Horwitz (1990), Kern (1995), and Schulz (1996) have argued that mismatches between foreign language students’ and teachers’ expectations can negatively affect the students’ satisfaction and lead to the discontinuation of study. Kern (1995) compared individual teacher’s perceptions of effective teaching practices with those of the students. Barcelos and Kalaja (2003) demonstrated that teachers’ and students’ beliefs about second language acquisition are experiential, dynamic, socially constructed, and changeable.
Data envelopment analysis (DEA) has been applied in various industries, such as: electricity sector (Cherchye & Post, 2003), healthcare services (Worthington, 2004), high-tech industry (Lai, 2007), transport (Yang, 2005), and accounting industry (Lee, 2009). In addition, DEA has also been used to assess the efficiency of higher education institutions: Ahn, Arnold, Charne, and Cooper (1989) on US universities in 1981-1985, and Glass, Mckillop, and O’Roruke (1998) on UK universities in 1989–1992. An assortment of methodological approaches have been employed in an effort to resolve the problem of efficiency measurement, from early studies which use ordinary least-squares (OLS) regression methods (Johnes & Taylor, 1990), to more recent studies which use frontier methods such as data envelopment analysis (DEA) (Abbott & Doucouliagos, 2003; Johnes, 2005). However, few studies measured efficiency at the departmental level (Madden, Savage, & Kemp, 1997 on economics departments in Australian universities; Johnes & Johnes, 1993 on economics departments in the UK in 1984–1988; Colbert, Levary, & Shaner, 2000, on MBA programs in the US).

Fu and Huang (2009) conducted a survey of recent college graduates in 2003 and collected different dimensions of performance indicators, including college graduate performance in the job market after graduation and student satisfaction with regard to the school environment and curriculum, as the student’s devotion to the school and its related activities. They used an output-oriented BCC type of DEA model to provide useful information to prospective students in terms of their choices regarding which college to join and to evaluate of the relative resource use efficiency of schools for school administrators. As far as we know, scholars who do research in the field of DEA tend to work on colleges or departments of management and business performance. It would be interesting to focus on language learning performance and notably to study the performance of non-native students of English (English as a Second Language or ESL).

**Methodology and chosen key items**

DEA is an attractive tool because it can measure relative efficiency of higher education institutions from commonly available performance indicators. Concerning the students’ learning performance, the input and output indicators become the important attributes for the periodical evaluation undertaken by the department, the university, and the Ministry of Education. This paper aims at designing a learning performance mechanism (the three circles in color) as illustrated in figure 1. Each year, students who enter university have different background and characteristics. Even though the freshmen follow the same training, they meet different teachers providing different teaching efforts. As students have different learning efforts, the learning results will be unpredictable. The 4 following categories, teachers, students, input dimensions, and output dimensions, vary directly each semester. They can be classified as major dynamic items in the learning performance mechanism. The objective of this mechanism is to identify the main input indicators (the richness of course content, the diversity of accessed multiple learning channels…) having a significant impact on the students’ learning performance (the students’ final grades, the knowledge level at the end of academic training, learning skills, employment rate…) generally classified as the main output indicators. The input and output indicators describing this type of learning performance should better be quantitative, so as to be compared to different evaluated units.

![Figure 1. Evaluation diagram of learning performance mechanism](image-url)
In figure 1, the mechanism is composed by the DEA model, the results treating, and the results interpreting. It can tell us whether the selected indicators have a significant impact on the learning results or not. If not, the input or the output indicators should be replaced. Then, the procedure should be repeated until we find the most influential indicators. This evaluating process is presented by the sign with a double sided arrow.

**DEA Model**

The domain of inquiry of DEA is a set of entities, commonly called decision making units (DMUs), that is the evaluated units, which receive multiple inputs and produce multiple outputs (Lee, 2009; Lin et al., 2009). The purpose of the DEA is to establish the relative efficiency of each DMU within a sample (Samoilenko & Osei-Bryson, 2008).

**Charnes-Cooper-Rhodes (CCR) model**

Charnes, Cooper, and Rhodes (1978) expanded Farrell’s (1957) efficiency measurement concept of multiple inputs and single output to the concept of multiple inputs and multiple outputs converted to single virtual input and output by linear combination. They estimated efficiency frontier by the ratio of two linear combinations and measured the relative efficiency of each DMU in constant returns to scale (CRS). The constant returns to scale represents the fact that the DMU’s inputs and outputs reach a state of optimal configuration, without the need of any adjustment from the inputs and outputs. This method is now so called “Charnes-Cooper-Rhodes (CCR) model or CCR model”. The efficiency value of CCR model is the overall technical efficiency of the DMU.

This research adopts the evaluating method—DEA to build up the learning performance mechanism and to perform the efficiency evaluations of a specific course. We investigate the operation performance of DMUs by analyzing these input items and by interpreting the output items according to different domain knowledge. Thus, the DMUs will be the classes that have this course; the input items could be the background or the learning effort of students, etc.; the output items could be the results of learning, such as: score, satisfaction, and so on.

Through the analysis of a specific evaluating method, we can better understand the operational efficiency of DMUs and provide references of concrete and practical strategies for those units with lower operating efficiency. That is, we can focus on the learning performance of each class through the quantitative analysis and provide some concrete and practical learning or teaching strategies for the classes with lower average scores. This notion can be explained by the efficient frontier curve which analyzes, under certain circumstances, how much effort is necessary for the output performance to come close to the efficient frontier. In our study, we focus firstly, under the same input resources, on the gap between the actual output performance and the target output performance. That is, we would like to clarify how much improvement is necessary to reach the optimal performance of outputs. It is also possible to realize the minimum input resources necessary by fixing the output resources.

**Data selecting—Input and output dimensions**

The characteristics of the research object are as follows:

2. They follow the same training program of English conversation for one semester to meet the homogeneity of the evaluated object.
3. A total of 18 students’ classes taught by full-time teachers (part-time teachers are not included in this research in order for teachers’ characteristics to be more consistent) are selected as the decision making units (DMUs), that is the evaluated units. They are named from D1 to D18.
4. There are 3 classes per semester. Each class contains around 50 students.

The specification of the outputs and inputs is a crucial first step in DEA. The input and output data is based on the average score of the student survey of teachers at the end of each semester for each class. Four dimensions are chosen as follows to represent the input and output items for the evaluation model.

**Input dimensions:**

1. The richness of course content: it refers to the degree of teachers’ professional knowledge for the preparation of teaching materials.
2. The diversity of accessed multiple learning channels: it indicates whether teachers can increase students’ learning interest and learning motivation.
Output dimensions:
O1. The positive degree of teaching attitude: it signifies whether teachers can positively respond to students’ questions and the maturity of teachers’ teaching skill and communication skill.
O2. The students’ learning performance: it indicates students’ learning performance after receiving a period of language training.

All the data acquired are fed into the learning performance mechanism designed for this research. The numerical results are treated and then interpreted in the following sections.

**Correlation analysis of input and output items**

Generally speaking, the correlation of the input items and output items in the evaluated units of DEA is commonly verified by statistics method, such as: regression analysis, factor analysis and correlation coefficient test, in order to understand whether the principle of Isotonicity is satisfied and the degree of the correlation between output items and input items. The correlation analysis used in this study is the Pearson correlation coefficient test. The higher the Pearson correlation coefficient is, the more closely the relationship between two variables will be; on the contrary, the lower the correlation coefficient is, the lower the correlation between two variables will be. In general, the Pearson correlation coefficient of 0.8 or above represents a very high correlation; the value of 0.6 to 0.8 represents a high correlation; the value of 0.2 to 0.4 represents a low correlation; the value inferior to 0.2 represents the extremely low correlation or not correlated. The input and output items listed in the Table 1 are abbreviated by I1, I2, and O1, O2, respectively. The correlation coefficients among these 4 items are all above 0.8 with significant levels at 1%. This shows a very high degree of correlation. The principle of Isotonicity is satisfied.

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Inputs</th>
<th>I1 (Richness of teaching material)</th>
<th>I2 (Diversity of learning channels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1 (Positive degree of teaching attitude)</td>
<td>0.974***</td>
<td>0.802***</td>
<td></td>
</tr>
<tr>
<td>O2 (Students’ learning performance)</td>
<td>0.903***</td>
<td>0.878***</td>
<td></td>
</tr>
</tbody>
</table>

**Empirical results and Suggestions**

The results of numerical analysis are used to clarify whether the existing teaching methods can achieve the desired results and what are the improved methods. This study can provide suggestions to teachers and students about how to make a better use of limited teaching and learning resources. The research results acquired by applying DEA are expected to indicate whether existing teaching scale is in optimal size, and whether students’ learning efforts and teachers’ teaching efforts will reach the expected performance. The learning performance mechanism can also be applied to other fields or other languages in future studies.

**Efficiency analysis of learning performance**

The efficiency value of CCR model is the overall technical efficiency of the evaluated unit. If the efficiency value equals to 1, the evaluated unit is efficient; if the efficiency value is less than 1, the evaluated unit is inefficient (Lee, 2009; Lin et al., 2009). This study analyzes the learning performance by using Frontier Analyst. The CCR score listed in Table 2 refers to the overall technical efficiency in the CCR model for 18 DMUs, named from D1 to D18. The average efficiency is 0.986. The overall technical efficiency of the DMUs D1, D4, D6, D10 and D13 show the best performance with value of 1. That is, their CCR Score are all on the Frontier curve without the need of further improvement in the inputs and outputs.

Taiwanese students are quite shy and do not like to express their opinion and speak a foreign language in public, especially in front of their classmates. Teachers are suggested to encourage them to practice during the class. They should find a balance between correcting students’ mistakes and motivating them so that they are not afraid to participate. As to students, they have to show their efforts during the training and accept criticism. However, if they are over criticized by their teachers, they will probably lose their motivation. It is always preferable to tell students in private what their problems are (pronunciation, speak louder, articulate, grammatical mistakes, content and vocabulary too poor, etc…). It is important they do not feel humiliated in public.
In Table 2, the column “Improvement degree” reveals how much improvement is necessary for the DMU and in what dimension. Since this empirical result is output oriented, we emphasize firstly on how much the insufficiency of output performance is under the current input resources; that is without additional input effort. That explains why the values of input dimensions, I1 and I2, are always 0 or negative. For example, the class D3’s overall technical efficiency is the lowest. There is still 4.6% of effort to do in the positive degree of teaching attitude and the students’ learning performance. That is, the teacher is suggested to respond to students’ questions more positively with more detailed explanation and to improve the teaching skill and communication skill so as to meet students’ needs. As for the case of class D9, the improvement value of I2 is -0.5%. That is, the teacher is suggested to slightly reduce the quantity of teaching materials. So the students could better assimilate the basic and important information of the course, and enhance their learning performance.

The column “Refs” indicates the number of times the other DMUs are referring to it. For example, there are 12 DMUs referring to the class D4. No DMUs will refer to the inefficient DMUs; this explains why their Refs values are all equal to 0. The column “Peers” indicates the number of times the inefficient DMUs refer to other efficient DMUs. 14 DMUs are referring to efficient DMUs. For example, the class D3 refers 3 times to other DMUs. It is suggested that experienced teachers help their colleagues and give them advices and ideas on how to make their class more attractive.

**Table 2. Overall technical efficiency of evaluated units under the CCR model**

<table>
<thead>
<tr>
<th>DMU name</th>
<th>CCR Score</th>
<th>Improvement degree (%)</th>
<th>Refs</th>
<th>Peers</th>
<th>DMU name</th>
<th>CCR Score</th>
<th>Improvement degree (%)</th>
<th>Refs</th>
<th>Peers</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>0.982</td>
<td>1.8</td>
<td>0</td>
<td>0</td>
<td>D10</td>
<td>0.997</td>
<td>0.2</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>D2</td>
<td>1.9</td>
<td>4.3</td>
<td>0</td>
<td>0</td>
<td>D11</td>
<td>0.972</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D3</td>
<td>4.6</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
<td>D12</td>
<td>0.972</td>
<td>1.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D4</td>
<td>1.2</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>D13</td>
<td>0.972</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D5</td>
<td>2.4</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>D14</td>
<td>0.972</td>
<td>1.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D6</td>
<td>1.2</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>D15</td>
<td>0.972</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D7</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>D16</td>
<td>0.972</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D8</td>
<td>4.3</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>D17</td>
<td>0.972</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D9</td>
<td>1.8</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>D18</td>
<td>0.972</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average 0.986</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Average 0.986</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conclusion**

McGowan and Graham (2009) studied the four factors contributing to improved teaching, such as active/practical learning, teacher/student interactions, clear expectations/learning outcomes, and faculty preparation. In our paper, we emphasized on four different dimensions: two inputs (the richness of course content, the diversity of accessed multiple learning channels) and two outputs (the positive degree of teaching attitude and the students’ learning performance). We use DEA to analyze the learning performance so as to obtain the numerical results and to give concrete suggestions.

We observe that the average overall technical efficiency is 0.986. Five DMUs (about 28% of all the DMUs) show the best performance with value of 1 and do not need any improvement in the inputs or in the outputs. It means that both teachers and students feel at ease and are motivated to work. The atmosphere in the class is good and students feel at ease to speak English. 13 inefficient DMUs have overall technical efficiency values (CCR score) smaller than 1. Students are more afraid to speak English during the class and are unable to assimilate the entire contents of the course. Some students think that their teacher has not enough professional knowledge and experience to teach a course of English conversation. Moreover, the teacher probably needs to improve the learning channels, such as language learning websites, learning softwares, online courses, computer-assisted language learning (CALL), etc…. D3, with the lowest overall technical efficiency, still needs to do 4.6% of effort in the positive degree of teaching attitude and the students’ learning performance. The teacher should respond to students’ questions more positively and improve the teaching and communication skills to meet students’ needs. A total of 4 DMUs have Refs values, since no improvement in input and output items is needed for them. D4 is the DMU most referred to and performs best: there are 12 inefficient DMUs referring to it due to its excellent performance in teaching material, and learning channels.
The results of this study not only give indications about teaching effectiveness of English conversation courses, but satisfy the objectives of enforcing Higher Education institutions' competitiveness, as well as the goals of the Ministry of Education.

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