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APPLICATION OF DATA ENVELOPE ANALYSIS (DEA) EFFECTIVENESS MODELS: EXAMPLE APPLICATION FOR INTERNATIONAL HOTELS IN TAIWAN AND ISSUES IN USING PARTICULAR MODELS

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Abstract

The paper introduces a Taiwan situation and reviews recent data envelope analysis (DEA) efficiency measurement literature as part of considering efficiency measurement for tourism operations. This research focuses on showing that using fuzzy multiple objective linear functional programming (FMOLFP) to calculate an efficiency ratio can

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be more appropriate, reliable and practical than using either of two other DEA models. The research examines formulations of DEA efficiency including how three DEA efficiency measurement methods work and why alternative methods have evolved. Advantages of using the FMOLFP method are considered. Efficiency results are presented for Taiwan to illustrate what results one gets using DEA methods.

Keywords: *Data envelope analysis, fuzzy linear functional programming, multiple objective linear functional programming, decision-making unit, efficient operation*

Prologue

International hotels in Taiwan have suffered from an imbalance between supply and demand. This imbalance is caused by the decrease of marginal growth in inbound tourism and rapid, growth in outbound flows. The average profits of Taiwan's international hotels (before taxes) in 2000 were: Taipei 10.27%, Hualien 0.96%, Taoyuan, Hsinchu and Miaoli 16.4%, Kaohsiung 23.93%, Taichung 26.63% and sightseeing area 8.23% (Taiwan Tourism Bureau, 2000). This shows that international hotels in Taiwan in general had low profits or had losses. However, there are regional disparities. Can those disparities be understood and can understanding them contribute to increased profitability?

An obvious way to improve profit is to improve the efficiency of operation. An obvious way to examine efficiency is to examine how output in dollars relates to input in dollars. However, in the end, one may spend a lot of effort and gain little insight from computing a number of efficiency values in this way. Recent research on efficiency measurement offers the opportunity to measure efficiency in innovative ways. Farrell (1957) is the first person to suggest the concept of production frontier. He introduced the idea, illustrated in Figure 1. One see that values associated with inputs and outputs define a surface/frontier. Other than for random variation, observations cannot go beyond the frontier because an efficiency of 1, of 100%, cannot be exceeded. In other words, data on operations define an *envelope*. One can refer to *envelopment* of data. By studying where points are in an envelope one can study efficiency. In 1978, data envelope/envelopment analysis was introduced by Charnes, Cooper, and Rhodes (1978). Since then many different models have been developed by various researchers. Therefore, there are numerous models and the selection of an appropriate model depends on the nature of production-technology. Bibliographies including thousands of articles are available (Seiford, 1999; Emrouznejad, 2001). There

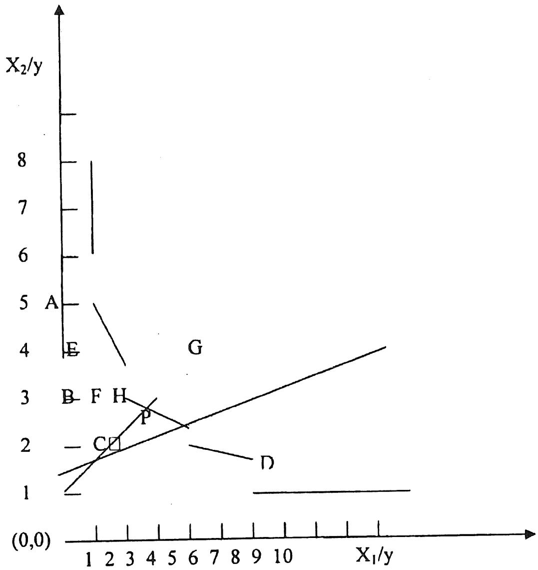

Figure 1: Data Envelope Diagram for 2 Inputs and 1 Output

is even a 2004 book that is available for download (Emrouznejad & Podinovski, 2004).

Tourism Related Literature Review

One finds a growing literature on DEA. DEA has been used to assess efficiency in a number of types of applications, either in not-for-profit entities or in profit-oriented industries (Wöber, 2002). There is a growing number of DEA applications in the hotel sector. Morey and Dittman (1995) gathered input-output data for 54 hotels of a national chain in the United States. Using data for each individual hotel in the sample, they applied DEA to generate a "composite efficient benchmark general manager' which acts as a scorecard for the hotel under review. Yan, Chang-Hua (1997) has considered the managerial efficiency of 50 international hotels in Taiwan between 1992-1994. This research was based on a DEA methodology. The result of this research showed that only 14 had relatively high managerial efficiency (28%). Johns, Howcroft, and Drake (1997) used DEA to monitor and benchmark productivity in a chain of 15 hotels. Data for a 12-month period were used. DEA was found to be useful for diagnosing and identifying outstanding behaviour in terms of their measured productivity and gross profits. Avkiran (1999) used seasonal time series data for a small set of

Australian hotel companies (23 units) in a case-study-like presentation. Cheng (2000) combined studying managerial efficiency of 25 international hotels in the Taipei area using DEA methodology with conducting customer satisfaction surveys. This allowed him to show 44% of chosen hotels have relatively high managerial efficiency and that this was related to satisfaction. Anderson, Fok, and Scott (2000) employed DEA to measure various forms of efficiency levels. The findings revealed that the hotel industry is highly inefficient with a mean overall efficiency measure of approximately 42%. Using the DEA approach, Tarim, Dener, and Tarim (2000) measured the relative efficiency of four- and five-star hotels in Antalys, Turkey; 21 hotels provided information on the three output (net profit, occupancy rate and customer loyalty) and three input (investment costs, number of personnel, periodical administration expenses) measures. Chang and Huang (2001) have used a DEA model to analyze 25 international hotels in Taipei area. This research applied DEA modeling to calculate managerial efficiency such as overall efficiency, pure technical efficiency and size efficiency. This allowed concluding that 9 hotels had high overall efficiency (36%), 12 hotels were technically efficient (48%) and 14 hotels were size efficient (56%).

The above studies demonstrated the practicality of the DEA method and that using it has opened new possibilities to interpret the efficiency of different hotel categories in competitive terms. One could say that using the DEA model to evaluate managerial efficiency of tourism related operations has become popular. However, citing results does not highlight problems and complex analysis matters. The number of input and output factors can influence the outcome of research. With too many input variables, there is a possibility of "de-concentrating" the difference between units being studied (DMU). Also use of a particular method can result in falsely high efficiencies (Lu, 2001).

Research Objectives and Strategy

By presenting information about 3 forms of DEA (models) and applying these to real data for Taiwan, the goal of this research is to achieve the following objectives:

1. Presentation of three DEA models, including how they work and thus how issues arise regarding their use.

2. Discussion of actual results of applying the three models so one sees the kind of results obtained and gains an appreciation of having (1) a sound and relatively easily used computational method; and (2) results in which one can have confidence.

The paper proceeds in several steps. The DEA concept and the three models are introduced in such a way that one sees the general ideas behind them. Why one modifies earlier models to have results appropriate to a particular application is a key matter. Having introduced models, data and estimation results for Taiwan are presented. The practical value of DEA results are discussed using the Taiwan example. A discussion and conclusion section provides an overview of matters considered as well as introducing practical considerations and research matters that should be addressed in the tourism literature.

Three DEA Models: Their Nature and Differences

1. DEA Modelling Ideas and the CCR Model

As introduced earlier, the principle behind DEA is that observed values can be used to define an *efficiency frontier*. One can think of observations defining a boundary, frontier or envelope. The boundary/frontier/envelope occurs because as efficiency is pushed toward its limit of 1, efficient operations congregate near, or at least help demarcate, the boundary set by efficient production.

In consideration of efficient operation it is conventional to consider decision-making units (DMU). Now, it may seem reasonable to focus on the efficiency of particular production units (e.g., on particular hotel properties). However, it can be reasonable to recognize that decisions are not going to be made in relation to particular production units. In fact, in the case of government concern with the tourism industry, the only valid management concern at the production unit level may be compliance with laws and regulations. However, in terms of a national tourism strategy, there can be a legitimate aggregate concern with the performance of tourism offerings (production units) in areas of a country or that serve particular market segments. In this respect, Taiwan may be interested in groupings of international hotels in Taiwan while a hotel chain might be interested in performance of either their competitors, as a group, or in their particular properties. In the case of geography, knowing that there are geographic efficiency differences can lead to wise decisions in government expenditure of resources. In Taiwan recognizing appropriate DMU is important because wise decisions are needed in a multi-billion tourism development program that started in 2002 and continues to 2008. This program deals with areas of Taiwan as well as particular markets. The DMU used in the Taiwan example presented in this paper is just one grouping of information that is necessary in studying tourism to plan, manage and monitor making changes.

For DMU, the DEA approach to evaluating efficiency involves "mapping" the inputs and outputs of DMU (or inputs or outputs Lovell & Pastor, 1999; Odeck,

2005) into a space. This is done to establish a frontier. Because graphic illustrations are restricted to a 2-dimensional page, consider, for example, "mapping" of inputs (x_1, x_2) and a single output (y) yielding Figure 1. In the figure, one sees a frontier defined by the points A, B, C and D. Points on this frontier are considered efficient in input/output terms. If a DMU does not map to the frontier (points E, F, G, H), it has an efficiency less than 1 (<100%). In the figure, P is the intersection of the line $\overline{OF}$ with the line forming the *frontier* $\overline{BC}$. The formula for calculating an efficiency value is:

$DMU_F = \frac{\overline{OP}}{\overline{OF}}$ where $\overline{OF}$ and $\overline{OP}$ are segments from the origin to F and P.

The CCR DEA Model and its Estimation.

Charnes, Copper and Rhodes' (1978) seminal DEA model, often designated as the CCR model, is used to measure efficiency by calculating productivity under fixed profit, multiple inputs and multiple outputs. Efficiency is to be maximized subject to conditions. One allows multipliers of inputs and outputs to be computed that determines efficiency as a weighted sum of outputs divided by the weighted sum of inputs. Therefore, for each input and output one determines weights V_i and U_r, respectively. The weights are usually designated by as vectors $U=(U_1,\ldots,U_s)$ and $V=(V_1,\ldots,U_m)$. Because U and V vectors for DMU_k are computed conditionally on efficiencies for other DMU (see Charnes, Copper & Rhodes 1978 or DEA texts such as Thanassoulis, 2001), one obtains different weights for each DMU.

$$\text{Maximizing efficiency value } DMU_K = Z_k = \frac{\sum_{r=1}^{s} U_r \cdot y_{rk}}{\sum_{i=1}^{m} V_i \cdot x_{ik}}$$

subject to conditions and

where there are n DMU; m input types; and

s output types.

Software for CCR estimation is included with texts (e.g. Thanassoulis, 2001; William et al., 1999).

The weights associated with inputs and outputs can be described as showing the importance of the inputs and outputs defining efficiency and thus can, under certain conditions, be used in identifying areas of good or bad performance. However, one must note that one has efficiency values defined differently. If one has one weight for a variable for DMU_k and another for it DMU_l, it is somewhat like measuring in centimetres in one case and inches in another. In mathematical terms there are "projections" into different linear spaces. Therefore certain comparisons DMU_k really should not be made. Furthermore, allowing different U and V for each DMU_k can result in many DMU_k having higher efficiency values than they should. If, in fact, it is reasonable to consider that one U-V pair should apply to all DMU_k, one has caused a situation like occurs when one "force fits" a regression by computing too many regression coefficients.

2. DEA Model by Chiang, Chin-I and Tzeng, Gwo-Hshiung (CT2000) - Efficiency Measuring Method

Chiang and Tzeng (2000) have addressed the problems of finding a U-V vector pair that applies to all DMU. Instead of looking for U_k and V_i, one is seeking a U and a V that will result in the maximum value of an inefficient DMU_k over all DMU.

They formulated calculation of efficiency values of each DMU as a multiple objective linear functional programming (MOLFP) problem. Using their method one searches for the DMU (e.g., k) with lowest efficiency value. Having found it, the goal becomes determining U and V to maximize k's efficiency value. The description of this as a MAX-MIN method comes from finding a minimum efficiency DMU (k) and then setting U and V for it based on maximizing its efficiency. Estimation was done using LINGO software (see http://lindo.com/lingom.html).

Using the CT2000 method, solving for efficiencies and interpreting those found is simpler than using the CCR model because one is just looking for one U-V pair (for m V_m and s U_s). What is more, when one determines vectors U and V that apply to all DMU, then comparison between DMU is based on shared weighting factors. Given that there should be common values, or that this is a good approximation, comparison of U_k and V_i between models to assess factors influencing is justified along a particular dimension) and thus comparison of efficiency values is justified.

The CT2000 calculation method can distort efficiency values. Clearly, setting U and V based on only one of many DMU sacrifices information so results can be highly vulnerable to statistical variability or measurement error/differences. Furthermore, because the unit used to define U-V is the most deviant one, one is vulnerable to setting weights based on a unit that, for some reason, should not be compared to others using the same weights.

3. A DEA Fuzzy Linear Functional Programming Model

To make better use of information than occurs with the MAX-MIN calculation one can use a fuzzy linear functional programming to reduce the multiple objective linear functional programming problem to a simpler problem (a single objective problem). The approach is embodied in equation form by the following in which one refers to $ì_k$ as the efficiency achievement of DMU_k:

$$Maximize \sum_{k=1}^{n} \mu_k$$

Subject to:

$$\mu_k = \frac{Z_k - Z_L}{Z_R - Z_L} \qquad for \quad all \quad k = 1,2,..,n$$

where the Z_k are are efficiency estimates as defined above.

$$\frac{\sum_{r=1}^{s} U_r \cdot y_{rk}}{\sum_{i=1}^{m} V_i \cdot x_{ik}} \leq 1 \qquad for \quad all \quad kk = 1,2,...,n$$

Ur□ Vi□ 0□ZL: lowest efficiency value; Z_R : highest efficiency value;

There is no intent to pursue details regarding the formulation introduced. Chiang and Tzeng (2000) pursue the matter of DEA efficiency measurement using fuzzy multiple objectives programming. The important matter to recognize is that one can employ software that is becoming easily used and readily available, to compute a single U-V pair based on all DMU. By doing this one avoids the risk of assuming that a U-V pair that applies to a particular low/lower efficiency DMU applies to all DMU. If getting one U-V pair for all DMU is desirable, it seems clear that it is best to get one that reflects the structure of all the data not a potentially deviant small part of it.

Data Used in Making Estimates for Taiwan

This research uses observations of the input and output for Taiwan's international hotels group to DMU as specified in Table 1. Locations of the cities mentioned can be found on most maps of Taiwan. No map is provided since the actual locations of the cities are irrelevant to the analysis.

Table 1: *Inputs and Outputs Variables of International Hotels in Different Areas*

Variables	Inputs			Outputs	
Area	Employees	Rooms	Expenditure (Million)	Profit (Million)	Occupancy (Room/day)
Taipei	12260	9314	20628	2425	6808.5
Kaohsiung	3177	2615	4165	3974	1510.7
Taichun	1630	1438	2388	2326	807.0
Hualien	653	1037	731	761	426.1
Sightseeing	1412	1581	1973	1955	928.5
THM	852	1327	1031	1125	752.1

*THM is Taoyuan, Hsinchu and Miaoli; dollars are in "New Taiwan" dollars, NT (30 NT H" 1.0 $US).

The data in Table 1 are from the "Monthly Report on Tourist Hotel Operations in Taiwan" (Taiwan Tourism Bureau, 2000). From the table, one sees that 3 input and 2 output variables were used. As it is not the goal of this research to give definitive guidance on variables, it is just noted that the variables chosen are obviously important in considering hotel efficiency. Some comment on numbers of variables to use and properties of those variables are provided in the discussion below.

Computations and Results

The results of computing efficiencies for data in Table 1 are shown in Table 2. Hotels in Taipei, Taoyuan, Hsinchu and Miaoli area show highest efficiency values. Hotels in Hualien and sightseeing area are in second place. Hotels in Kaohsiung

Table 2: Efficiency Values Calculated by Different DEA Models

Efficiency Value Area	CCR	CT2000	Fuzzy	Profit% (before tax)	Profit rating
Taipei	1.0	1.0	1.0	10.27	2
Kaohsiung	0.754	0.843	0.828	-23.93	5
Taichun	0.840	0.840	0.840	-26.63	6
Hualien	0.934	0.840	0.934	0.96	3
Sightseeing	0.946	0.901	0.876	-8.23	4
THM	1.	1.0	1.0	16.4	1

and Taichung area have the lowest efficiency values. Given that profitability went into determining efficiency, efficiency being related to profitability is not unexpected. Nevertheless, the different methods yield some quite different results. CCR and Fuzzy results are closer to each other than to CT2000 results for Hualien but not for Kaohsiung. For sightseeing hotels CT2000 is between CCR and Fuzzy. One could say one has potentially useful results but inconsistency raises some questions.

As pointed out earlier, inconsistencies between methods may reflect using different methodologies. For international hotels serving the sightseeing market, factors of production may differ so efficiency should be calculated using the CCR model. Further study would be needed to determine the sensitive of solutions to various influences. Still, given that for the cities (not sightseeing) one U-V pair is appropriate, it is possible to say that for cities, one should have most confidence in fuzzy efficiencies.

It seems fair to say that the efficiency results are useful. However, it is also fair to say that they have just been presented as an example. In a real situation more variables should be considered and there should be consideration of DMU being comparable in terms of production. Sightseeing areas may involve a different kind of operation than cities (be seasonal) and thus require different U-V criteria than cities. By actually looking at U-V values computed based on the CCR model, one may see city/region differences in Taiwan that should be considered in planning. One must be careful in what analysis assumptions are accepted (e.g., does one have a set of DMU to which one U-V pair should apply).

Discussion and Conclusions

In addition to being a widely accepted way to measure efficiency in a variety of contexts, what can one say about DEA? Well, one has seen that it can be used to produce useful results for tourism managers and policy makers. A particular merit is that it is non-statistical and non-parametric method that can be used with data generated by administrative processes. By non-statistical, it is meant that using it is not based on any assumptions about statistical distribution; the need to make other assumptions regarding production is another matter. However, just regarding data, one can use administrative data that is routinely accumulated. Therefore, the cost of data can be minimal and, because one gets data year after year, new results can be obtained from year to year by just continuing to process data that are produced. Regarding non-parametric, one does not have to assume a particular functional relationship between the inputs and outputs. These aspects of the nature of DEA enhance its usefulness.

As mentioned in the introduction, different DEA models are formulated to deal with different problems. Until "fuzzy" formulations were created DEA was criticized because of its nonstochastic nature. Some may still maintain that basically all deviations from the frontier are attributed to inefficiency. Alternative, stochastic frontier methods exist (Coelli et al., 1998; Lovell & Kumbhakar, 2000) and may merit consideration. The concern raised with CT2000 solutions may be related to concern about sensitivity to outliers (Coelli et al., 1998). However, there is disagreement about the influence of outliers (Thompson et al., 1994).

Actually, what the authors see as really important for the appropriate and effective application of DEA in tourism studies is the development of examples that guide people with limited technical knowledge in applying DEA. In that regard, this paper only serves in a very limited way to highlight the fact that arguments can be made for using certain DEA models. However, the Taiwan example presented probably raises more questions than it answers. An extensive casebook that defines situations to which particular models fit is necessary. Furthermore, guidance on doing sensitivity analysis of solutions, comparing results from different methods to assess whether assumptions are met and other matters need to be covered with a specific orientation to tourism operations and efficiency.

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