DEA of Assurance Region Malmquist Index: An Illustration with International Tourist Hotels in Taiwan

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Abstract - This study supplements Malmquist Index calculation of basic DEA model, and includes weights of input and output factors so as to more precisely measure the vertical productivity change of industries. The model we proposed revises the Assurance Region Malmquist Index (AR-MI) by combining importance of weights with Malmquist Index. Analytic Hierarchy Process is used to acquire the weights of input and output items, and empirical analysis is conducted on operational performance of international tourist hotels in Taiwan by the modified model. The results shows that: (1) long-term productivity of overall industry grows and the main reason is due to technical transformation instead of growth of technical efficiency; (2) returns to scale of hotel industry declines, which indicates the severe competition in the industry; (3) growth or decline of international tourist hotels is closely related to government promotion for industry development.

Keywords: Assurance Region, Malmquist Index, DEA, Analytical Hierarchy Analysis, international tourist hotels

1 Introduction

In the tourism industry, tourist hotels are multifunctional places for lodging, shopping, and various social activities of tourists. According to statistics of the Tourism Bureau [1], Ministry of Transportation and Communications, in 2006, the average expenditure of each tourist in Taiwan in tourist hotels was 44.74% of daily consumption/per person. Therefore, service quality and operational performance of tourist hotels are the keys of tourism industry. Hotel industry in Taiwan can be divided into ordinary tourist hotels and international tourist hotels. In 1992-2006, the numbers of ordinary tourist hotels and rooms reduce from 42 hotels and 4,706 rooms to 29 hotels and 3,265 rooms by 31%; numbers of international tourist hotels and rooms increase from 47 hotels and 15,018 rooms to 60 hotels and 17,830 rooms by 18.72%. It indicates that larger scale international tourist hotels are the mainstream in the market. Thus, performance management of international tourist hotels is an important researcher topic.

Past studies have indicated the importance of weights of input and output. Sun and Lu [2] included influence of weights in calculation of model, but the weights of input and output variables were fixed and possible relative relations among weight ratios might be neglected. Therefore, this study attempts to integrate the importance weights of input and output items in research of Färe et al. [3] on Malmquist Index of year-to-year productivity change in order to complete research method.

The subjects of this study were 34 international tourist hotels in Taiwan. Data were sourced from the “Operational analysis and report of international tourist hotels in Taiwan” of 1997-2006 edited by Tourism Bureau, Ministry of Transportation and Communications. The research purposes are below: (1) to expand the research field of DEA to serve as a reference to future studies; (2) to analyze the overall operational performance of international tourist hotels and long-term productivity change; (3) to provide references for hotel industry to gradually enhance performance.

The remainder of this paper is organized as follows: Section 2 describes the research method and modified model, data and variable selection; Section 3 discusses the empirical analysis. Finally, Section 4 gives conclusions and suggestions.

2 Research method

Due to limitation of the space, this study does not indicate the basic model of DEA and only suggest the related parts. For introduction of basic theory of DEA, please see Cooper, Seiford and Tone [30].

2.1 Assurance Region Malmquist Index

In original CCR model, weights of input and output items are acquired by the model regarding the optimized efficiency value of different DMUs. However, the weights are not based on importance of the variables. Thus, there is no proper and reasonable explanation in terms of economics or managerial implication.

Malmquist Index model proposed by Färe et al. [3] is only based on CCR and does not consider importance of input and output items. In practice, input and output items reveal different percentages of importance. By assessing the weights
of input or output items, real efficiency measurement can be used.

Assurance Region (AR) is also based on CCR; however, this model includes upper and lower limit of weights of input and output variables. Thus, it can separate inefficient DMU from efficient DMU judged by CCR. Therefore, Assurance Region will more effectively indicate different performance degrees of DMU. In order to more precisely measure vertical productivity change of industry, based on Malmquist Index model, this study combines specific model concept and includes weight importance in Malmquist Index model to propose Assurance Region Malmquist Index (AR-MI).

2.1.1 Weight setting of input and output items

It is assumed that weights of input and output items are \( v_i = (v_1, \ldots, v_m) \) and \( u_r = (u_1, \ldots, u_s) \), importance of input and output is shown in the following conditions:

\[
\begin{align*}
L_{1,2} \leq \frac{v_2}{v_1} & \leq U_{1,2} \\
L_{1,2} \leq \frac{u_2}{u_1} & \leq U_{1,2}
\end{align*}
\]

In Eq. (1), \( L_{1,2} \) and \( U_{1,2} \) represent upper and lower limits of weight ratio \( v_2/v_1 \) of input items. \( L_{1,2} \) and \( U_{1,2} \) in Eq. (2) indicate upper and lower limits of weight ratio \( u_2/u_1 \) of output items.

2.1.2 Malmquist Index calculation by restricted distance function

Färe et al. [3] combined Malmquist Index, modified Total Factor Productivity (TFP), defined by Caves, Christensen and Diewert [32] and calculated distance function proposed by Shepherd [33] through nonparametric techniques and geometric mean. They turned Total Factor Productivity change into product of Technical Efficiency Change (TECH) and Technology Change (TCH). Ray and Desli [34] further replaced fixed Returns to Scale by changed Returns to Scale. They not only calculated Technology Change of changed Returns to Scale, but also divided Technical Efficiency Change into Pure Technical Efficiency Change (PTECH) and Scale Efficiency Change (SECH). Meanings of the terms of input-oriented Malmquist Index are skipped in this paper due to conference presentation limit.

2.2 Selection of decision-making units

Source of research data is the “Analysis and report of operation in international tourist hotels of Taiwan (1997-2006)” edited by Tourism Bureau [1], Ministry of Transportation and Communications. In the report, the hotels which close out and are reorganized of the years are eliminated. Thus, data are complete and continuous. The subjects in study are 34 international tourist hotels which are listed in the report in consecutive ten years.

2.3 Variables selection

We summarized the variables used in the literature cited in Section 2.2 and obtained a total of 5 inputs (number of guest rooms, number of employees, total area of catering department, total operating expenses and catering expenses) and 6 outputs (total operating revenues, average occupancy rate, average room rate, average production value per employee, occupancy revenues, catering revenues). This research topic explores the overall operational performance; therefore, the input item “catering expenses” is part of the total operating expenses and can be eliminated. The output items “occupancy revenues” and “catering revenues” are both part of the total operating revenues, so these two items are also eliminated.

We selected a total of 34 DMUs and 8 input/output items, in line with Golany and Roll [35], who suggested that the number of DMUs should be at least twice the aggregation of input and output items. Table 1 presents descriptive statistics for our data set. To ensure the accurate representation of statistics, we calculated the arithmetic mean of all numbers of these hotels over the past 10 years. Table 2 shows the correlations that were obtained. A positive
correlation is observed between the input and output variables. In other words, an increase in some inputs will lead to an increase in some outputs. This is consistent with the hypothesis of constant returns to scale that has been used in this research.

2.4 Weight

Weights in this study are acquired upon Analytic Hierarchy Process (AHP) proposed by Satty [36]. Integration of simplicity and flexibility of AHP and DEA will effectively result in relative importance weights among variables Cooper, Seiford and Tone [30]. Inference of relative weights can be upon experts’ opinions in AHP questionnaire. Questionnaire survey is based on convenience sampling and field interview.

3 Empirical analysis

In this section, consistency test of AHP questionnaire and acquisition of weights of input and output items are conducted by Microsoft Office Excel 2007. The distance function of Assurance Region Malmquist Index is calculated by self-designed Marco program and “planning and solution” of Microsoft Office Excel 2007.

3.1 Weight calculation of input and output items

A total of 12 questionnaires were returned, including five hotels (Landis Hotel, Evergreen Hotel, Howard Hotel, United Hotel and Hotel Holiday Garden). Two questionnaires that did not pass the consistency ratio test were eliminated. In 10 valid questionnaires, post distribution is shown below: 2 assistant general managers, 2 managers of front office, 2 directors of human resource department, 2 directors of marketing planning department, 1 financial director and 1 director of counter department; as to distribution of educational level, there are 1 doctors and 9 bachelors; regarding ages, 5 subjects are 31—40 years old and 5 subjects are 41—50 years old; as to seniority in international tourist hotels, 2 subjects are 1—5 years, 2 subjects are 5—10 years, 4 subjects are 10—20 years and 2 subjects are above 20 years. Weight ratio of marginal input is shown in Table 3.

3.2 Analysis on year-to-year productivity change

In this section, four distance functions are obtained by Equations (1)-(4), empirical analysis is conducted on nine year-to-year productivity changes according to the operation of international tourist hotels in Taiwan in 1998-2007 by Malmquist Index deconstructed by Ray and Delsi [34].

3.2.1 Analysis on Technology Change

Regarding hotel industry, Technology Change is efficiency frontier change caused by increase of asset input or result input operation of research innovation. Technology Change values of hotels in different periods increase or decrease. Far Eastern Plaza Hotel (H16) grows for eight times in 9 periods. Sheraton (H10) and Royal Hotel (H11) grows for 7 times; Hotel Riverview Taipei (H04), Santos Hotel (H07), Howard Hotel (H12), Grand Formosa Regent (H14) and Evergreen Hotel (H24) grow for six times; growth of Hotel National (H22) and The Grand Hotel Kaohsiung (H30) is lower for three times in 9 periods; in 1998-1999, 1999-2000, 2001-2002, 2003-2004, 2004-2005 and 2006-2007, over half of hotels have Technology Change increased. In 2000-2001, 2002-2003 and 2005-2006, most of hotels have Technology Change decreased.

3.2.2 Analysis on technical efficiency change

Technical Efficiency consists of Pure Technical Efficiency and Scale Efficiency, including technical capacity and business scale of enhancement of hotel image and service quality which result in relative position change of DMU in production set. The changes are described below.

i. Technical efficiency change
As to Technical Efficiency Change of hotels in different periods, United Hotel (H09) and Ambassador Hotel Kaohsiung (H19) grow for six times in 9 periods. Royal Hotel (H11), Howard Hotel (H12), Sherwood Hotel (H15) and Far Eastern Plaza Hotel (H16) only have lower growth twice in 9 periods; in 1999-2000, 2000-2001, 2002-2003 and 2005-2006, over half of hotels have Technical Efficiency increase and in 1998-1999, 2001-2002, 2003-2004, 2004-2005 and 2006-2007, most of hotels have Technical Efficiency decreased.

ii. Pure technical efficiency change
Factors of Pure Technical Efficiency Change can include overall marketing of hotels, managerial process, personnel quality, resource fit and broadening sources of income and reducing expenditure, etc. As to Pure Technical Efficiency Change of hotels in different periods, Hotel Kingdom (H17), Hotel Holiday Garden (H18), Ambassador Hotel Kaohsiung (H19), Howard Hotel Kaohsiung (H21) and Hotel National (H22) grow for six times in 9 periods. Grand Hyatt Taipei (H13), Grand Formosa Regent (H14), Far Eastern Plaza Hotel (H16) and Hotel China (H29) do not have Pure Technical Efficiency changed in 9 periods; in 1999-2000, 2002-2003 and 2005-2006, over half of hotels have growth of Pure Technical Efficiency and in 1998-1999, 2003-2004 and 2006-2007, most of hotels have Pure Technical Efficiency decreased.

iii. Scale efficiency change
Growth of Scale Efficiency means hotels are approximate to MPSS. Regarding Scale Efficiency Change of hotels in different periods, Ambassador Hotel Kaohsiung (H19) grow for six times in nine periods; Royal Hotel (H11), Sherwood Hotel (H15), Far Eastern Plaza Hotel (H16) and Hotel Kingdom (H17) only have lower growth for two times in nine periods. In 2000-2001 and 2002-2003, over half of hotels have growth of Scale Efficiency and in 1998-1999, 1999-2000, 2001-2002, 2003-2004, 2004-2005, 2005-2006 and 2006-2007, most of hotels have Scale Efficiency decreased.

3.2.3 Analysis on total factor productivity change
Total Factor Productivity is product of Technology Change and Technical Efficiency Change and it can be general index of operational performance measurement by tangible input and output. As to Total Factor Productivity change of hotels in different periods, Hotel Riverview Taipei (H04) grow for eight times in nine periods; Ambassador Hotel (H02), Grand Formosa Regent (H14), Ambassador Hotel Kaohsiung (H19) and Howard Hotel Taichung (H25) grow for seven times in nine periods; Howard Hotel (H12), Sherwood Hotel (H15), Grand Han-Lai Hotel (H20), Marshal Hotel (H26), Parkview Hotel (H28) and Tainan Hotel (H33) only have three times of lower growth in nine periods; in 1998-1999, 1999-2000, 2001-2002, 2003-2004 and 2004-2005, over half of hotels have Total Factor Productivity increased and in 2000-2001, 2002-2003, 2005-2006 and 2006-2007, over half of hotels have Total Factor Productivity decreased.

4 Conclusions and suggestions
This study proposes expansion model of DEA and analyzes operation of international tourist hotels in Taiwan in 1998 - 2007. The findings not only extend research field of DEA, but also allow international tourist hotels in Taiwan to recognize their industrial position and competitive environment and function as criterion for resource or strategy adjustment. Conclusions are summarized as follows:

i. Proposal of expanded model of DEA:
Malmquist Index can indicate year-to-year change of long-term industrial development. In order to acquire more precise efficiency measurement, this study includes weights of input and output variables in the original model and proposes input-oriented Assurance Region Malmquist Index model.

ii. Productivity of hotel industry has been growing for long term and the main reason is Technology Change:
In 1998-2007, geometric mean of Total Factor Productivity of overall industry is 1.010. It demonstrates that in the past ten years, productivity of hotel industry is increasing. Among 21 hotels with increasing Total Factor Productivity, most of them have increased Technology Change and decreased Technical Efficiency. Among 12 hotels with decreasing Total Factor Productivity, most of them have increased Technology Change and declined Technical Efficiency; mean of Technology Change in overall industry is 1.061 which is increased by 0.061%, Technical Efficiency Change is 0.951 which is reduced by 0.049%. It is inferred that in the past ten years, the main reason of growth of overall hotel industry productivity is Technology Change. It implies that hotels value enhancement of asset input or R&D and innovative capacity. Therefore, for most of hotels, at present, they should enhance Technical Efficiency such as marketing or service quality in order to increase productivity.

iii. Returns to Scale of overall industry decrease, and it indicates that the hotel industry is highly competitive:
Geometric mean of Scale Efficiency Change is 0.955 which decreases. 8 hotels have increased Scale Efficiency Change and 25 of them have decreased change. It demonstrates that in the past ten years, average production scale of hotel industry deviates from MPSS. It implies that growth of tourism industry in Taiwan does not catch up with increase of international tourist hotels. Therefore, Scale Efficiency of overall industry decreases in highly competitive environment. The government should propose more effective measure in order to enhance development of tourism industry in Taiwan.

iv. Growth and decline of international tourist hotels are
closely related to governmental measures to enhance industrial development:

Regarding long-term change of Total Factor Productivity in 1998-2007, Total Factor Productivity of five periods grows and Total Factor Productivity of four periods decreases. It shows that operational performance of international tourist hotels was affected by foreign and domestic political and economic events.

In diverse research themes, there are various expanded models of DEA. Besides the propriety of research topics, these studies mostly modify previously established models and compare with them to revise and improve the modified model. Malmquist Index which indicates long-term industrial change is only based on radial orientation as scale. Although this study takes into account of weight limit, it can still develop Assurance Region Malmquist Index model upon slack analysis.

5 References


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