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A MACRO ANALYSIS OF TAIWAN'S INTERNATIONAL TOURIST HOTEL INDUSTRY BY USING THE SLIDING WINDOW METHOD

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Abstract This paper proposes an alternative data envelopment analysis for assessing the operational performance of 46 international tourist hotels (ITHs) in Taiwan over the period 1997-2002. This study is the first research that combines the discriminant power of a slack-based measure and the dynamic view of window analysis in applying DEA. It is shown that the trend of mean managerial efficiency is increasing, whereas the variation converges. Most ITHs operate at decreasing returns to scale, indicating that ITHs are facing a highly competitive environment. Taiwan's 921 earthquake in 1999, the 911 incident in 2001, and the compulsory government subsidies all play key roles which affect the ITHs' managerial performance for different operating characteristics in the short term. Results also indicate that differences in management style do have a very significant influence upon ITHs' performance over time (1997-2002). Finally, the efficiency/profitability matrix of ITHs is further examined.

Keywords: DEA, liner programming, tourism, window analysis

1. Introduction

The purpose of this paper is to examine the managerial performance of Taiwan's international tourist hotels (ITHs) for the period 1997-2002, using a two-stage procedure. In the first-stage analysis, the slack-based measure (SBM) model [29] and the window analysis [11] are combined in order to sharpen the efficiency estimates over the period (1997-2002) with multiple operating data in both inputs and outputs. In the second stage, a Tobit regression analysis is employed to analyze the operating characteristics for exploring the variation of managerial performance among ITHs. The results of this study can assist an ITH manager to improve the operational management of ITHs.

Taiwan's ITH industry is experiencing competitive pressure due to the rapid growth of new ITHs, a decreasing number of tourists, deteriorating economic conditions, and inefficient management. Inefficient management is the factor that top management can pay attention to. In other words, the total number of Taiwan's ITHs has increased from 44 in 1985 to 62 in 2004, whereas the total number of ordinary tourist hotels has decreased from 79 in 1985 to 25 in 2004. Moreover, as a result of the Asia Financial Crisis in 1997, Taiwan's 921 earthquake in 1999, the 911 incident in 2001, the second Gulf War in 2003 and the SARS epidemic in 2003, the number of foreign tourists visiting Taiwan has been decreasing. With the external reasons stated above and inefficient hotel management, eight four-star ITHs closed down in 1998. To survive, the island's ITHs need to identify the critical factors to improve their operating efficiency and managerial performance.

Most prior research studies about ITHs were conducted in developed countries, while few were performed in emerging countries. Among these small numbers of studies, cross sectional data are used to investigate the performance of ITHs. However, an analysis based on longitudinal data can better understand the performance trend and stability. Key ITH operating characteristics, such as location, management styles, etc., are needed to be figured out, and then insights that cause imperfectly competitive conditions for some ITHs can be understood. We conduct herein an examination of the impacts of these operating characteristics on ITHs' performances and which would add great value for the local ITH industry.

This paper is organized as follows. Related prior studies which have influenced this study are discussed in section 2. The design of the efficiency models and an introduction of the methodology are addressed in Section 3. The test results and interpretations are provided in section 4. Finally, section 5 concludes with the finding of this study.

2. Literature Review

Much of the research on the hotel industry often uses performance indicators. These studies mostly focus on single indicators such as cost-volume-profit, sales receipt information, the concept of perishable asset revenue management to measure performance (PARM), lodging index, and RevPar, etc. ([19], [22], [17], [30], [23], [31], [32], [6], [18]). Although these accounting and financial indicators in terms of simple ratios provide important and useful information for benchmarking a hotel's financial performance, a hotel's performance is a complex phenomenon requiring more than any single criterion to characterize it. Consequently, a number of studies have argued that a multi-factor performance measurement model may be used ([1], [5], [13]). To overcome the drawback of accounting and ratio measures mentioned above, data envelopment analysis (DEA) has been used as a metric for measuring hotel performance over the last decade. We now summarize the six main studies that have used DEA to investigate the relative efficiency of hotels.

Morey and Dittman [24] implemented DEA to measure the general-manager performances of 54 owner-managed hotels of a nationally known chain, geographically dispersed over the continental United States. This study describes that the average efficiency score of the general-managers is 0.89; the lowest efficiency is 0.64; and it provides the owners of single properties with the ability to benchmark a manager's performance. A stochastic frontier approach [2] is used to evaluate the managerial efficiency of 48 hotels using 1994 operating data. These hotels represent a broad cross section of hotels from various regions of the United States. The result reveals the hotel industry operating at an 89.4% efficiency score, whereas the highest and lowest hotel efficiency scores are 92.1% and 84.3%, respectively. Their study also provides evidence that the market for lodging services seems to be operating efficiently.

Anderson et al.[1] re-evaluated the managerial efficiency of 48 firms using the data in Anderson et al.[2]. The study reports that the hotel industry is inefficient with a mean overall efficiency measure of approximately 42%. These findings contradict previous studies, which find the hotel industry to be nearly perfectly competitive and efficient. The major reason that their results are different is that they use a more comprehensive efficiency measure and are able to capture more inefficiency. Tsaur [34] used DEA to measure the operating efficiency of 53 international tourist hotels in Taiwan using 1996-1998 operating data. The study reports that the mean hotel efficiency score operates at 87.33%. Among these 53 hotels, 28.3% of them were operating on the efficient frontier. Thus, the market for lodging services seems to be operating efficiently in Taiwan.

Hwang and Chang [20] utilized DEA and the Malmquist productivity index to measure the managerial performance of 45 Taiwanese hotels in 1998 and the efficiency change of them from 1994 to 1998. Results indicate that the entire industry can be partitioned into six clusters based on relative managerial efficiency and efficiency change. Effective management strategies are developed specifically to each of the six clusters of hotels. Chiang et al. [16] used DEA to measure 25 Taipei ITHs' performances under three operational styles of ITHs using 2000 operating data. The finding shows that not all of Taipei's franchised or managed ITHs performed more efficient than the independent ones. Table 1 presents the characteristics of the six main studies using DEA. Although the hotel efficiency has been widely discussed in the previous literature and the DEA technique is frequently used to explore this topic, there are still some important points not touched.

Table 1: Literature survey of the DEA model on the hotel industry

Authors	DEA Model	Units	Inputs	Outputs
Morey and Dittman (1995)	CCR	54 owner-managed hotels of the continental United States, 1993.	(1) number of rooms, (2) average occupancy rate, (3) average daily rate, (4) number of employees, (5) resource expenditures.	(1) total room revenue, (2) facilities-satisfactionn index, (3) services-satisfaction index.
Anderson, Fish, Xia, and Michello(1999)	Stochastic Frontier approach	48 hotels/motels of the United States, 1994.	(1) average employee annual wage, (2) average price of a room, (3)average price of food and beverage operations, (4) average price of casino operations, (5) average price of hotel operations, (6) average price of other expenses.	(1) total revenues generated from various hotel services.
Anderson, Fok, and Scott (2000)	CCR BCC	48 hotels/motels of the United States, 1994.	(1) average employee annual wage, (2) average price of a room, (3)average price of food and beverage operations, (4) average price of casino operations, (5) average price of hotel operations, (6) average price of other expenses.	(1) total revenues generated from various hotel services.
Tsaur (2000)	CCR	53 ITHs of Taiwan, 1996-1998.	(1) total operating expenses, (2) number of employees, (3) number of rooms, (4) total floor space of the catering division.	(1) total operating revenues, (2) number of rooms occupied, (3) average daily rate, (4) average production value per employee in the catering division.
Hwang and Chang (2003)	CCR Malmquist Index	45 ITHs of Taiwan, 1994, 1998.	(1) number of full-time employees, (2) guest rooms, (3) total area of meal department, (4) operating expenses.	@(1) room revenue, (2) food beverages revenue, (3) other revenues.
Chiang, Tsai, and Wang (2004)	BCC	25 hotels of Taipei, 2000.	(1) hotel rooms, (2) food and beverage capacity, (3) number of employees, (4) total cost of the hotel	(1) Yielding index, (2) F&B revenue, (3) miscellaneous.

First, most DEA analysis are cross sectional, comparing the performance of decision making units (DMUs) in the same time period. One window analysis approach performing the longitudinal design is used to compare cross-sectional runs across the number of time periods (1997-2002) in the present study. This approach introduces variability into the analysis because it treats the performance of DMU in each time period as independent from performance in the previous period. Such an approach would allow a dynamic view of the multidimensional performance of ITHs.

Second, in the DEA literature, a DEA window analysis [11] based upon radial DEA efficiency scores is developed to observe performance trends of DMUs over time. In DEA, non-zero input and output slacks are very likely to present after the radial efficiency score improvement. Often, these non-zero slack values represent a substantial amount of inefficiency. Therefore, in order to fully measure the inefficiency in DMU's performance, it is very important to also consider the inefficiency represented by the non-zero slacks in the DEA window analysis. This study proposes a slack-based DEA window analysis which allows a full evaluation of inefficiency in a DMUs performance. By using slack-based efficiency measure, we obtain more appropriate performance trends for inefficient DMUs.

Third, the various ITHs/DMUs characteristics are evaluated to determine their relationships to the ITH industry efficiency. The key ITH operating characteristics (i.e., international chain or independent-owned, metropolitan areas or resort areas, closeness to CKS international airport or not) are needed to be figured out, and then insights that cause imperfectly competitive conditions for some ITHs. The results will also aid operations managers in improving their ITHs by benchmarking their ITHs against similar ITHs.

3. Research Design

3.1. Performance model

The ITH industry provides guests with services such as accommodation, catering, entertainment, convention venues, social activities, and shopping. From a system perspective, organizational activities refer to the conversion of inputs in various resources to output. Output is a concrete measurement that an organization has reached its objectives. In this study the production approach is used to design the performance model - namely, managerial performance. The performance model measures the managerial performance of ITHs in using four inputs to produce five outputs. The choice of input and output variables used in the performance model can be traced to the literature (see Table 1.) and hotel operating reports published by Taiwan Tourism Bureau (TTB). For example, total area of the catering department appears as a measured input in Tsaur [34], and Hwang and Chang [20]. Similarly, average production value of per employee in the catering division appears as a measured output in Tsaur [34]. The input and output factors used in this study are defined as follows:

Input factors:

- Total operating expenses: theitems of operation expenses of international tourist hotels, as a whole, include salary and related expenses, catering costs, water and electricity fuel expenses, depreciation expenses, maintenance and repair costs, rent and so forth, measured in units of thousand NT$.
- Number of employees: refers to the number of individual employees that are involved in the operation of ITHs, including medium- and high-ranking executives, guest rooms and catering staff, cooks, maintenance crews, and repairmen.
- Number of guest rooms: refers to the amount of guest rooms that can be provided for rent by an ITH. Accordingly, the unit of measurement is simply "room", without subsequent adjustment being made for size or quality.
- Total area of catering division: refers to the total floor space used by the operational units of all the ITH's catering facilities, measured in square meters.

Output factors:

- Total operating revenues: the operational revenue of ITHs includes the income from guest rooms, catering services, laundry, stores, attached operating income, and service fees, measured in units of thousand NT$.

- Average occupancy rate: refers to the ratio between the actual number of guestrooms let and those available to be let.
- Average room rate: refers to the ratio between the income from guest rooms and the actual number of guest rooms, measured in "NT$/room."
- Average production value per employee in the catering division: refers to the ratio between total revenues from the catering division and the number of employees in the catering division, measured in "NT$/individual."
- Average production value of the catering division (per 36 square feet): refers to the ratio between total revenues from the catering division and the total floor space of catering division, measured in "NT$/ (per 36 square meters)."

3.2. Sample and data

This study investigates 46 ITHs in Taiwan, because those ITHs operated in the period 1997-2002. Each of these ITHs is treated as a decision making unit (DMU) in the DEA analysis. The 46 ITHs of various sizes and geographical dispersement are selected since they are officially ranked as either four or five 'plums'. Note that in Taiwan the highest rating of an ITH with five 'plums' is equivalent to five 'stars' in the U.S. The detailed information of these ITHs is shown in Appendix A. The performances of the ITHs are accessed based on the data obtained for the years 1997-2002. The data are extracted from the annual report of the Taiwan Tourism Bureau. Table 2 presents descriptive statistics for our dataset. Input and output data are reported as the total number throughout the year and can be found in The Operating Report of International Tourist Hotel in Taiwan published by the TTB [33]. These reports are commonly deemed valid and reliable and are available to the public.

Table 2: Descriptive statistics for the 46 ITHs in Taiwan (1997-2002)

Variables	Mean	Std. Dev.	Minimum	Maximum
Input Variables				
Total operating expenses (x_1)	555,327,886	532,893,894	18,115,527	2,324,213,657
Number of employees (x_2)	378	278	26	1,254
Number of guest rooms (x_3)	318	169	50	873
Total area of catering division (x_4)	1,273	1,595	48	12,073
Output Variables				
Total operating revenues (y_1)	620,319,358	655,237,145	15,379,118	3,041,667,278
Average occupancy rate (y_2)	61	15	11	90
Average room rate (y_3)	2,781	996	1,061	5,917
Average production value per employee in the catering division (y_4)	1,494,560	509,935	49,804	3,274,888
Average production value of catering division (y_5)	262,511	169,955	1,194	881,133

Table 3: Correlation coefficients among input and outputs

	Input Variables				Outnput Variables				
	x_1	x_2	x_3	x_4	y_1	y_2	y_3	y_4	y_5
x_1	1.00								
x_2	0.95	1.00							
x_3	0.84	0.83	1.00						
x_4	0.65	0.65	0.56	1.00					
y_1	0.98	0.93	0.83	0.64	1.00				
y_2	0.53	0.55	0.34	0.34	0.55	1.00			
y_3	0.59	0.51	0.30	0.26	0.61	0.55	1.00		
y_4	0.54	0.42	0.37	0.30	0.53	0.34	0.43	1.00	
y_5	0.41	0.42	0.23	0.16	0.47	0.51	0.58	0.40	1.00

Table 3 shows the correlation matrix of inputs x_i and outputs y_r. Notice that all the correlation coefficients are positive. Therefore, these inputs and outputs hold 'isotonicity' relations, and thus these variables are justified to be included in the model. Cooper et al. [14] suggested that the number of ITHs should be at least triple the number of inputs and outputs considered. In this study the number of ITHs is 138 (46x3) in every window, which is larger than triple the number of inputs (4)/outputs (5), or $138 > 3(4+5) = 27$. Consequently, the developed DEA model of this study holds a high construct validity.

3.3. Methodology

The SBM model, DEA window analysis, and Tobit regression analysis are employed in this study. SBM model is used to assess the performance of ITHs and simultaneously deal with input excesses and output shortfalls of the ITHs concerned. Window analysis is used to compare cross-section runs across the number of time periods in the study. Tobit regression analysis is utilized to examine the effects of different operating characteristics on the ITHs' performances. An introduction to the methodology used in this study follows.

3.3.1. SBM model

As described in Cooper et al. [15], there are a variety of DEA models to choose from. DEA models can be divided into radial models (e.g. the CCR by Charnes et al. [12], the BCC by Banker et al. [4]) and non-radial models (e.g. the Russell measure by Russell [25], the range-adjusted measure by Aida et al. [3], SBM by Tone [29]). For our analysis, we choose the SBM model as the appropriate version of DEA for this study. The SBM model has many desirable features which may explain why we are interested in using it to investigate the efficiency of converting multiple inputs into multiple outputs. These characteristics include: (1) this scalar measure deals directly with the input excesses and the output shortfalls of the ITHs concerned; (2) it is unit invariant and monotonically decreasing with respect to input excess and output shortfall; (3) this measure is determined only by consulting the reference-set of the ITHs and is not affected by statistics over the whole dataset. The output-oriented SBM model with variable returns to scale evaluates the efficiency of $ITH_o(x_{io},\ y_{ro})$ by solving the following linear program:

$$\eta_o = Min_{\lambda,s^+} \frac{1}{1+\frac{1}{s}(\sum_{r=1}^{s}\frac{s_r^+}{y_{ro}})} \tag{3.1}$$

$$\begin{aligned} s.t.\quad & \\ & x_{io} \geq \textstyle\sum_{j=1}^{n} x_{ij}\lambda_j, && i=1,...,m, \\ & y_{ro} = \textstyle\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+, && r=1,...,s, \\ & \textstyle\sum_{j=1}^{n} = 1, && j=1,...,n, \\ & \lambda_j \geq 0, s_r^+ \geq 0 \end{aligned}$$

Here, n is the number of ITHs, x_{ij} and y_{rj} are the levels of the ith input and rth output respectively at the jth ITH, and λ_j is the weight of the jth ITH. The $ITH_o(x_{io},\ y_{ro})$ is the ITH being evaluated. An ITH is called 'SBM efficient' if and only if $\eta_o^* = 1$. The value of λ_j indicates whether the jth ITH serves as an exemplar for ITH_o to follow. For instance, if $\lambda_j = 0.4$, then it denotes that ITH_o should learn 40% from the jth ITH and be placed on the target efficient output and input levels. However, if $\lambda_j = 0$, then the jth ITH is not an exemplar to ITH_o. Furthermore, according to the recent result of Banker and Thrall [7], this study easily estimates the returns to scale (RTS). If increasing returns to scale (IRS), then the ITH_o should expand. On the other hand, if decreasing returns to scale (DRS), then the ITH_o would benefit by downsizing.

3.3.2. Window analysis

In order to observe the performance trends of an ITH over the six-year period, a DEA window analysis based on the principle of moving averages is performed. In essence, each moving average is covered by a sliding window. An ITH performance in a particular period is contrasted with its own performance in other periods as well as to the performance of other ITHs. Charnes, et al. [11] illustrated the best procedure of window analysis in their work. The data used in this study are obtained for 46 ($n = 46$) ITHs/DMUs over six ($p = 6$) yearly periods. To perform the analysis using a three-year (w=3) window, we proceed as follows.

Each ITH is represented as if it is a different ITH for each of the three successive years in the first window (1997, 1998, and 1999), and an analysis of the 138 ($nw = 46 \times 3$) ITHs is performed by using SBM models to obtain sharper and more realistic efficiency estimates. The window is then shifted one period, and an analysis is performed on the second three-year set (1998, 1999, and 2000) of the 138 ITHs. The process continues in this manner, shifting the window forward one period each time and concluding with a final (fourth) analysis of 138 ITHs for the last three years (2000, 2001, and 2002). In general, one performs $p - w + 1$ separate analyses, where each analysis examines $n \times w$ ITHs.

3.3.3. Tobit regression model

Although the efficiency scores obtained from solving linear programming problems for the SBM models represent the ability of management to convert inputs into outputs at the current scale of operation, it is possible that some differences in operating characteristics may affect the ITHs' performance. Therefore, it is important for this study to determine which ITH characteristics have an influence upon variations in managerial efficiency across ITHs. Tobit regression analysis is employed to estimate the relationship between managerial efficiency scores and ITHs' operating characteristics unrelated to the inputs used in the SBM model. Specifically, the following model is estimated:

$$TE^{mean} = \alpha + Z\beta + \epsilon, \tag{3.2}$$

where TE^{mean} is a vector $n \times 1$ of mean managerial efficiency for all n ITHs; the scalar α and the $(d \times 1)$ vector β are unknown parameters to be estimated; Z is an $(n \times d)$ matrix of operating characteristics, and ϵ is an $(n \times 1)$ vector of residuals. Past approaches that have employed DEA to measure managerial efficiency followed up by regression techniques to assign variation in efficiency include Berger et al. [8], Carrington et al. [10] and Sun [28]. We identify three key characteristics that may affect the ITHs' performances. One can use a dummy variable to indicate different management styles: 1 for international chain and 0 for independent-owned. Likewise, a dummy variable is used to specify the location of an ITH: 1 for metropolitan and 0 for those located in a resort area. Another dummy variable is used to specify accessibility to CKS international airport (1 hour driving), where a value 1 indicates an ITH is located near it and 0 if it is not located near it.

4. Results and Discussion

This section reports the results obtained using the methods outlined in Section 3. First, the composition of the efficient frontier, the RTS, and the number of references to this ITH as a peer in each window are given in section 4.1, and this is followed by the managerial efficiency of ITHs in Section 4.2. This part analyzes trends and potential stability of managerial efficiency over the six-year period. Section 4.3 sheds light on the characteristics contributing to managerial efficiency, and Tobit regression analysis is used to determine which characteristics may influence the variations of managerial efficiency across ITHs. Moreover, the efficiency/profitability matrix of ITHs is further examined in Section 4.4.

4.1. Efficient frontier, returns to scale, and benchmark

The efficient frontier is the frontier (envelope) representing 'best performance' and is made up of the ITHs in every window which are most efficient in transforming their inputs into outputs. The composition of the efficient frontier for each window over the period 1997-2002 is shown in Appendix B. The ITHs with unity efficiency are those at the frontier. An ITH not on the frontier line indicates that its efficiency is less than one. Of the total 46 ITHs in the sample, 25 IHTs are efficient at least once in a sliding window during the time period 1997-2002. Twenty out of the 25 ITHs are below the 5th room-scale size (400<number of room<500). H06 and H30 are on the frontier for every window. Notice that H06 and H30 are on 8th room-scale size and 7th room-scale size, respectively. Twelve out of the 17 international chain ITHs are on the frontier at least once for the time period 1997-2002. This implies that aside from the scale of ITHs, management type is also an important factor affecting the performance of ITHs.

The distribution of RTS in Appendix B shows that 1% of the ITHs are operating at increasing returns to scale (IRS), 24% of ITHs are operating at constant returns to scale (CRS), and the remaining 75% of ITHs are at decreasing returns to scale (DRS). This result also reveals that ITHs are facing a highly competitive environment in Taiwan. Of particular interest here is to find out the best ITH which can serve as the benchmark of these efficient ITHs. A counting method counts the number of times an efficient ITH appears in the peer group of the inefficient ones. For instance, H30 has a count of 21 in the last column of Appendix B (Refs). An efficient ITH with a high count may be considered to be a genuinely efficient ITH ([11], [27], [26]). On the basis of market segmentation and geographical location variation [21], the benchmarks of metropolitan ITHs and resort ITHs are examined separately. Appendix B shows that among the 37 metropolitan ITHs in Taiwan, the Sherwood Hotel Taipei (H22) is the efficient ITH that is referred to the most by others. The Hotel Landis China Yangmingshan (H39) is the efficient ITH that is referred to the most by others among the 9 resort ITHs. In other words, the Sherwood Hotel Taipei and Hotel Landis China Yangmingshan are benchmarks for metropolitan ITHs and resort ITHs, respectively.

4.2. Managerial performance

Figure 1 shows the mean managerial efficiencies and corresponding standard deviations for ITHs. Notice that the trend of mean managerial efficiency is increasing whereas the variation converges. These results indicate that the overall managerial performance of the ITHs improved over the period.

To help interpret the result we note that the "Row Average" and "Std. Dev." (Appendix B) are other useful ways of analyzing the trends and potential stability problems in terms of managerial efficiency among ITHs. Totally, Appendix B shows that 11 out of the 46 ITHs exhibit improving behavior and the same improvement continues to be manifested with different datasets. These include H03, H05, H07, H08, H09, H13, H15, H23, H33, H35, and H41. Four out of the 46 ITHs exhibit deteriorating behavior and the same deterioration continues to be manifested with different datasets. These include H20, H25, H28, and H38. However, H03, H07, H09, H13, H25 H35, and H38 have a higher variance. Such an outcome may be due to the unusually low or high managerial efficiency. These ITHs desire further examination in a future study.

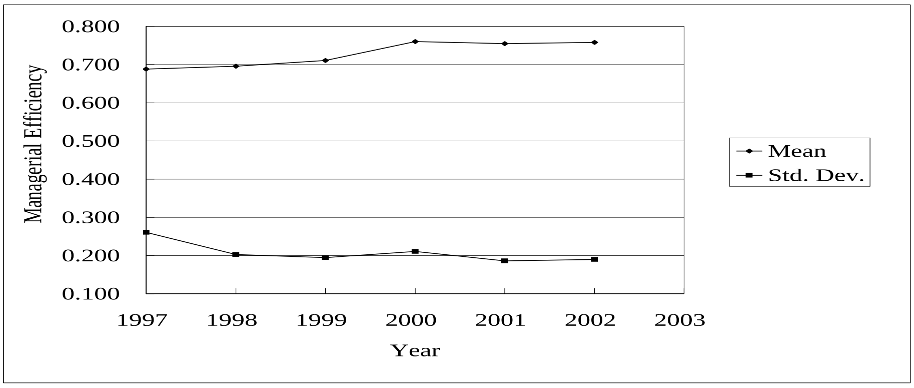

Figure 1: Managerial efficiency of ITH industry, 1997-2002

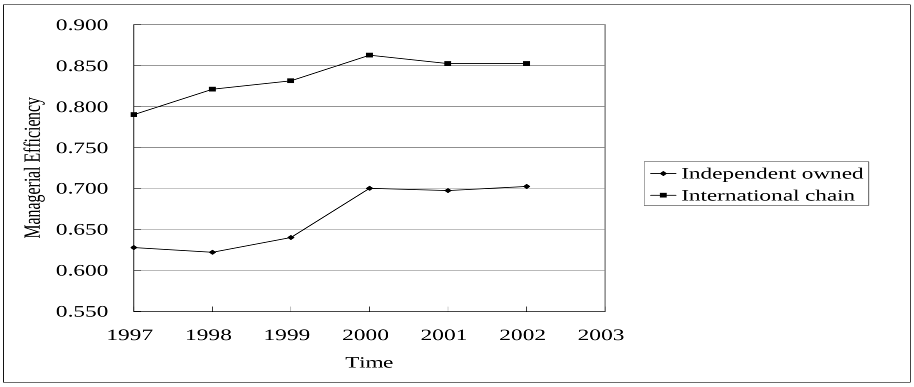

Figure 2: Managerial efficiency with management type of ITHs

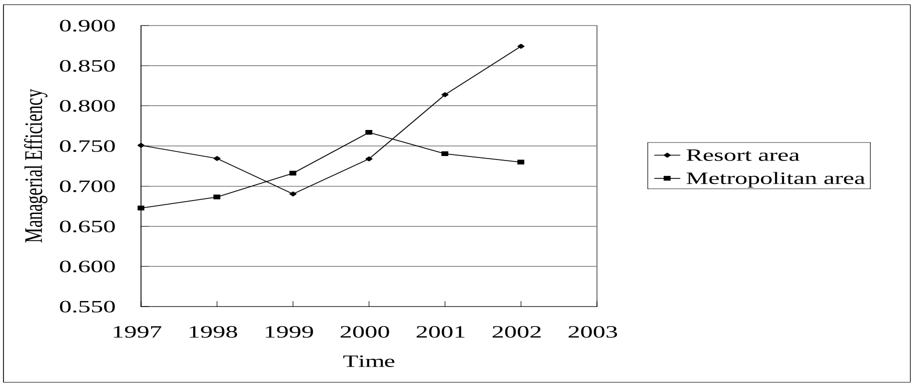

Figure 3: Managerial efficiency with location of ITHs

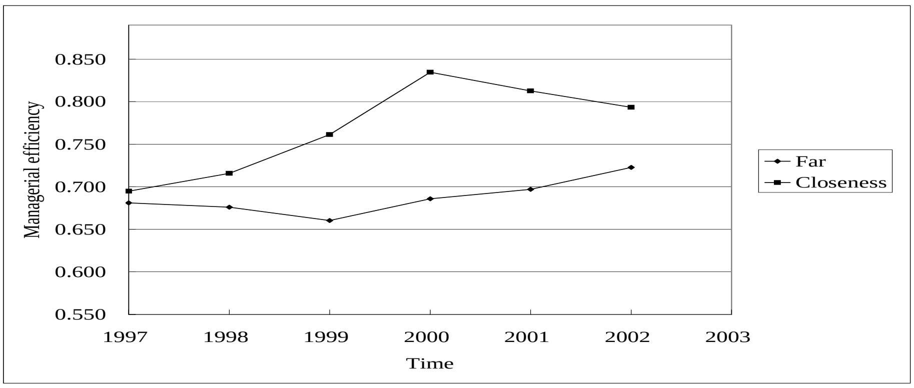

Figure 4: Managerial efficiency with closeness of ITHs to CKS International Airport

The mean window analysis score is 0.73, indicating the fact that the market for lodging services is not operating efficiently in Taiwan. According to Appendix B, 11 out of the 46 ITHs are found to have managerial efficiencies over 0.9%. This means that each of these eleven ITHs are more efficient than the remaining 35 ITHs. From Appendix B, one might find that high efficiency is associated with a low standard deviation. Among the eleven ITHs, six ITHs having an average efficiency score over 0.98 indicate that these ITHs were operating efficiently and stably over the six-year period. These ITHs are H06, H20, H22, H30, H39, and H42. Among the six ITHs, H06 and H30 have the highest mean managerial efficiency and the lowest standard deviation.

To determine whether differences exist in various ITH characteristics (i.e., international chain or independent-owned, metropolitan area or resort area, closeness to CKS international airport or not) for managerial efficiency, a non-parametric statistical analysis (Mann-Whitney test) is used [9] for unknown distribution scores. Bold-faced figures in Table 4 indicate statistical significance. Notice that there is a consistent significant, statistical difference on managerial efficiency between independent-owned and international chain ITHs. Moreover, the international chains consistently outperform the locals (Figure 2). This might be due to them having a better reputation, a brand image, internet marketing, an efficient reservation system, and economies of scale.

Figure 3 shows the major dip of the 921 earthquake (year 1999) to resort-type ITHs. These ITHs have regained their advantage since the year 2001 mainly due to government subsidies to government employees. Government subsidies provide support to government employees for domestic tours up to seven days with a ceiling of NT$16,000 annually. It is estimated that there are 570,000 government employees including military personnel. Figure 4 shows that the managerial efficiency with closeness of ITHs to CKS international airport is steady until the 911 incident in 2001 triggered a dip for the next two years. Notice also that due to the occurrence of the 921 earthquake in 1999 in Taiwan more foreigners come to Taiwan for business instead of leisure. The compulsory government subsidies also showed that they helped those ITHs far from CKS international airport.

Table 4: Non-parametric analysis of management style, location, and closeness to CKS

Characteristics			1997	1998	1999	2000	2001	2002
Management Style	Independent-owned	(Mean)	0.628	0.622	0.640	0.700	0.697	0.703
	International chain	(Mean)	0.790	0.821	0.832	0.863	0.853	0.853
	Mann-Whitney test	(p-value)	0.012*	0.001*	0.001*	0.022*	0.005*	0.006*
Location	Resort area	(Mean)	0.751	0.734	0.690	0.734	0.814	0.874
	Metropolitan area	(Mean)	0.673	0.686	0.716	0.767	0.740	0.730
	Mann-Whitney test	(p-value)	0.438	0.533	0.771	0.515	0.251	0.034*
Closeness to CKS	Far	(Mean)	0.681	0.676	0.660	0.686	0.697	0.723
	Close	(Mean)	0.695	0.716	0.761	0.835	0.813	0.793
	Mann-Whitney test	(p-value)	0.725	0.613	0.073	0.012*	0.038*	0.213

Note:*Statistically significant at 0.05 level.

4.3. Characteristics affecting hotel managerial performance

To determine whether operating characteristics affect the managerial performance of the ITHs, the obtained mean managerial efficiencies are regressed against the management style, location, and closeness to CKS international airport. The tobit regression results in Table 5 explain about 24.765% of the variation in managerial efficiency and the coefficient of management style is significant at the 5% level. The significance of management style confirms our prior finding based on the Mann-Whitney test. Consequently, we conclude that the managerial performance of ITHs is influenced by the management style over the period 1997-2002.

Table 5: Results of Tobit regression

	Coefficient	Std. Error	z-Statistic	P-value
Constant	0.6812	0.0587	11.6132	0.0000
Management Style	0.1535	0.0528	2.9083	0.0036*
Location	-0.0414	0.0738	-0.5610	0.5748
Closeness to CKS	0.0512	0.0606	0.8441	0.3986
R-Squared				0.2477

Note:*Statistically significant at 0.05 level.

4.4. Analysis of efficiency and profitability

To further illustrate the important relationship between efficiency and profitability, an efficiency/profitability matrix of ITHs is presented in Figure 5. All ITHs fall into four quadrants: stars, sleepers, dogs, and question marks. Each ITH is classified into a quadrant by examining (1) whether the mean managerial efficiency is equal to or less than 0.9, (2) whether the average profitability is greater than or smaller than 0. ITHs in the star quadrant (average profitable ≥ 0 and mean managerial efficiency ≥ 0.9) are the flagship ITHs including H02, H06, H10, H17, H18, H20, H22, H23, H30, H39, and H42. These ITHs falling into the zone of starts are about 64% international chain ITHs. This shows that the international chain ITHs have better competitive power and they should provide examples of operating practice.

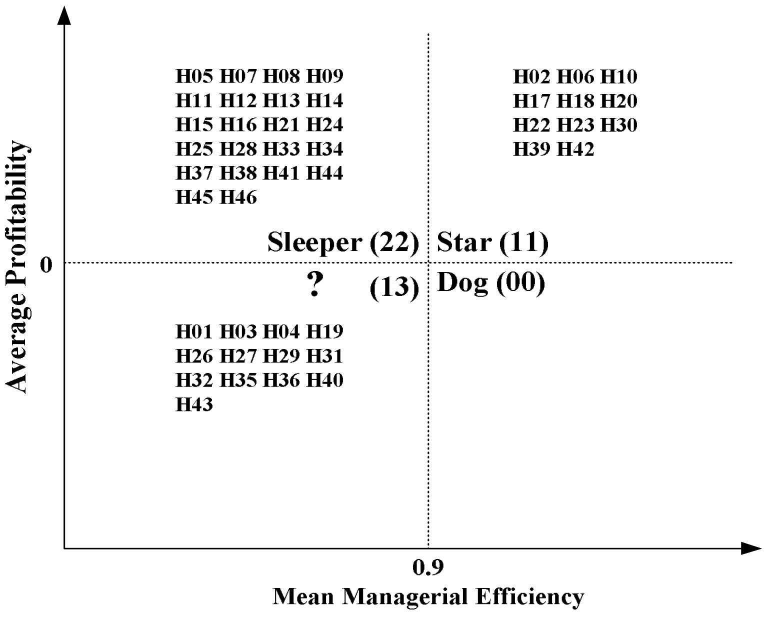

Figure 5: Mean managerial efficiency/average profitability matrix

The sleepers are profitable, but have a managerial efficiency less than 0.9 which indicates that they still have room for improving efficiency and are likely to see better profitability. We have 22 ITHs including H05, H07, H08, H09, H11, H12, H13, H14, H15, H16, H21, H24, H25, H28, H33, H34, H37, H38, H41, H44, H45, and H46 in this area. The quadrant of question marks has the potential for greater efficiency or possibly greater profitability. There are 13 ITHs including H01, H03, H04, H19, H26, H27, H29, H31, H32, H35, H36, H40, and H43. Attempts should be made to increase their efficiency and this may lead to greater profitability. The dogs are efficiently-operated ITHs with low profitability. There are no ITHs in this area.

5. Concluding Remarks

Both the SBM model and window analysis have been combined in order to examine the performance of the 46 ITHs in Taiwan over the period 1997-2002. This empirical study has shown that the mean window analysis score is 0.73, indicating that the market for lodging services does not operate efficiently in Taiwan. However, the overall managerial performance has steadily improved and the variance among all the ITHs has converged over the period.

This study also has found that (1) Most ITHs are operating at decreasing returns to scale (DRS), indicating that ITHs are facing a highly competitive environment in Taiwan; (2) the "count" method points out that the Sherwood Hotel Taipei and Hotel Landis China Yangmingshan are benchmarks for those in metropolitan and resort areas, respectively; (3) international chain ITHs have more robust competitive power, because they have a better reputation, brand image, internet marketing, an efficient reservation system, and economics of scale; (4) Taiwan's 921 earthquake in 1999 might crucially have affected the managerial efficiency of resort ITHs in the period 1999-2000; (5) the compulsory government subsidies significantly have affected the managerial efficiency of resort ITHs in the year 2002; (6) the 911 incident in 2001 significantly affected the managerial performance of ITHs close to CKS international airport in the year 2001. Results also indicate that differences in management style do have a very significant influence upon ITHs' managerial performance.

A few notes of caution are in order here. Our study is in terms of highly aggregated measures of outputs and inputs. There are important qualitative dimensions of outputs that are not taken into account; for example, quality of services, costumer satisfaction, and quality of employees. It would be desirable to treat these outputs explicitly in the models used in here. Our basic methodology would still remain valid, however. This study is the first research that has combined the discriminant power of SBM and the dynamic view of window analysis in applying DEA. Moreover, this alternative DEA method has provided Taiwanese ITHs' operations with insights into resource allocation and competitive advantage and could be compared with Malmquist index technique in the future. It is also hoped that the models and methods implemented in this study can bring about other related researches to a variety of industries.

References

[1] R.I. Anderson, R. Fok, and J. Scott: Hotel industry efficiency: an advanced linear programming examination. *American Business Review*, **18** (2000), 40–48.

[2] R.I. Anderson, M. Fish, Y. Xia, and F. Michello: Measuring efficiency in the hotel industry: a stochastic frontier approach. *Hospitality Management*, **18** (1999), 45–57.

[3] K. Aida, W.W. Cooper, J.T. Pastor, and T. Sueyoshi: Evaluating water supply services in Japan with RAM: A range-adjusted measure of inefficiency. *Omega, The International Journal of Management Science*, **26** (1998), 307–232.

[4] R.D. Banker, A. Charnes, and W.W. Cooper: Models for estimating technical and scale efficiencies in DEA. *European Journal of Operational Research*, **30** (1984), 1078–92.

[5] R.P. Bagozzi and L.W. Phillips: Representing and testing organizational theories: A holistic construal. *Administrative Science Quarterly*, **17** (1982), 459–489.

[6] M. Baker, and M. Riley: New perspectives on productivity in hotels: Some advances

and new directions. *International Journal of Hospitality Management*, **13** (1994), 297–311.

[7] R.D. Banker, and R.M. Thrall: Estimation of returns to scale using Data Envelopment Analysis. *European Journal of Operational Research*, **62** (1992), 74–84.

[8] A.N. Berger and L.J. Mester: Inside the bank box: what explains differences in the efficiencies of financial institutions. *Journal of Banking and Finance*, **21** (1997), 895–947.

[9] P.L. Brockett, and B. Golany: Using rank statistics for determining programmatic efficiency differences in data envelopment analysis. *Management Science*, **42** (1996), 466–472.

[10] R. Carrington, N. Puthucheary, D. Rose, and S. Yaisawarng: Performance measurement in government service provision: The case of police services in New South Wales. *Journal of Productivity Analysis*, **8** (1997), 415–430.

[11] A. Charnes, C.T. Clark, W.W. Cooper, and B. Golany: A development study of data envelopment analysis in measuring the efficiency of maintenance units in the U.S. Air Forces. *Annals of Operations Research*, **2** (1985), 95–112.

[12] A. Charnes, W.W. Cooper, and E. Rhodes: Measuring the efficiency of decision making units. *European Journal of Operational Research*, **2** (1978), 429–444.

[13] B.S. Chakravarthy: Measuring strategic performance. *Strategic Management Journal*, **7** (1986), 437–458.

[14] W.W. Cooper, S. Li, L.M. Seiford, K. Tone, R.M. Thrall, and J. Zhu: Sensitivity and stability analysis in DEA: Some recent developments. *Journal of Productivity Analysis*, **16** (2001), 31–47.

[15] W.W. Cooper, L.M. Seiford, and K. Tone: *Data envelopment analysis: a comprehensive text with models, applications, references and DEA-Solver software* (Kluwer Academic Publishers, London, 2000).

[16] W.E. Chiang, M.H. Tsai, and L.S. Wang: A DEA evaluation of Taipei hotels. *Annals of Tourism Research*, **31** (2004), 712–715.

[17] M.M. Coltman: *Hospitality Management Accounting* (CBI Publishers, Boston, 1978).

[18] C. Enz, and L. Canina: Best of time, the worst of times: differences in hotel performance following 9/11. *Cornell Hotel and Restaurant Administration Quarterly*, **43** (2002), 22–32.

[19] C.T. Fay, R.C. Rhoads, and R.L. Rosenblatt: *Managerial Accounting for Hospitality Service Industries* (Brown Publishers, Iowa, 1971).

[20] S.N. Hwang, and T.Y. Chang: Using data envelopment analysis to measure hotel managerial efficiency change in Taiwan. *Tourism Management*, **24** (2003), 357–369.

[21] J. Ismail, M.Dalor, and J. Mills: Using RevPar to analyze lodging-segment variability. *Cornell Hotel and Restaurant Administration Quarterly*, **43** (2002), 73–80.

[22] R.K. Jaedicke and A.A. Robichek: Cost-volume-profit analysis under conditions of uncertainty. In A. Rappaport (ed.): *Information for Decision-Making-Quantative and Behavioural Dimensions (2nd. Edition)* (Prentice-Hall Publishers, Englewood, 1975).

[23] S.E. Kimes: The basics of yield management. *Cornell Hotel and Restaurant Administration Quarterly*, **30** (1989), 14–19.

[24] R.C. Morey and D.A. Dittman: Evaluating a hotel GM's performance: a case in benchmarking. *Cornell Hotel and Restaurant Administration Quarterly*, **36** (1995), 30–35.

[25] R.R. Russell: On the axiomatic approach to the measurement of technical efficiency. In W. Eichhorn (ed.): *Measurement in Economics* (Heidelberg, Physica,1988), 207–217.

[26] T.R. Sexton, A.M. Leiken, A.H. Nolan, S. Liss, A. Hogan, and R.H. Silkman: Evaluating managerial efficiency of veterans' administration centers using data envelopment analysis. *Medical Care*, **27** (1989), 1175–1188.

[27] P. Smith, and D. Mayston: Measuring efficiency in the public sector. *Omega, International Journal of Management Science*, **20** (1987), 569–586.

[28] S. Sun: Measuring the relative efficiency of police precincts using data envelopment analysis. *Socio-Economic Planning Sciences*, **36** (2002), 51–71.

[29] K. Tone: A slacks-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research*, **130** (2001), 498–509.

[30] C.S. Van Doren and L.D. Gustke: Spatial analysis of the U.S. lodging industry. *Annals of Tourism Research*, **9** (1982), 543–563.

[31] K. Wassenaar, and E.R. Stafford: The lodging index: an economic indicator for the hotel/motel industry. *Journal of Travel Research*, **30** (1991), 18–21.

[32] B.S. Wijeysinghe: Breakeven occupancy for a hotel operation. *Management Accounting*, **71** (1993), 32–33.

[33] Taiwan Tourism Bureau: *The Operating Report of International Tourist Hotels in Taiwan* (Taiwan, Taipei, 1997-2002).

[34] S.H. Tsaur: The operating efficiency of international tourist hotels in Taiwan. *Asia Pacific Journal of Tourism Research*, **6** (2000), 29–37.

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Appendix A: The detailed information of ITHs in Taiwan

Hotel	Code	Room scale	Management style	Location	Closeness to CKS
The Grand Hotel	H01	3	0	1	1
The Ambassador Hotel	H02	4	1	1	1
Magnolia Crown Hotel	H03	5	0	1	1
Imperial Hotel Taipei	H04	5	1	1	1
Gloria Prince Hotel	H05	6	1	1	1
Emperor Hotel	H06	8	0	1	1
Hotel Riverview Taipei	H07	6	0	1	1
Caesar Park Hotel Taipei	H08	5	1	1	1
Gold China Hotel	H09	6	0	1	1
Brother Hotel	H10	6	0	1	1
Santos Hotel	H11	5	0	1	1
The Landis Ritz Hotel	H12	6	1	1	1
United Hotel	H13	6	0	1	1
Sheration Taipei Hotel	H14	2	1	1	1
Taipei Fortuna Hotel	H15	5	0	1	1
Holiday Inn Asiaworld Taipei	H16	1	0	1	1
Hotel Royal Taipei	H17	6	1	1	1
Howard Plaza Hotel	H18	2	0	1	1
Rebar Crown Plaza Hotel	H19	6	1	1	1
Grand Hyatt Taipei	H20	1	1	1	1
Grand Formosa Regent Taipei	H21	3	1	1	1
The Sherwood Hotel Taipei	H22	5	1	1	1
Far Eastern Plaza Hotel Taipei	H23	4	1	1	1
Hotel Kingdom	H24	5	0	1	0
Hotel Holiday Garden Kaohsiung	H25	6	0	1	0
The Ambassador Hotel Kaohsiung	H26	4	1	1	0
Han-Hsien International Hotel	H27	5	0	1	0
Grand Hi-Lai Hotel	H28	4	0	1	0
Howard Plaza Hotel Kaohsiung	H29	6	0	1	0
Park Hotel	H30	7	0	1	0
Hotel National	H31	4	0	1	0
Plaza International Hotel	H32	6	0	1	0
Evergreen Laurel Hotel Taichung	H33	5	0	1	0
Howard Plaza Hotel Taichung	H34	7	0	1	0
Astor Hotel	H35	7	0	0	0
Marshal Hotel	H36	6	0	0	0
Chinatrust Hotel Hualien	H37	6	0	0	0
Parkview Hotel	H38	5	0	0	0
Hotel Landis China Yangmingshan	H39	8	1	0	0
Grand Hotel Kaohsiung	H40	7	0	0	0
Caesar Park Hotel Kenting	H41	6	1	0	0
Hotel Royal Chihpen Spa	H42	7	1	0	0
Grand Formosa Hotel, Taroko	H43	6	1	0	0
Taoyuan Holiday Hotel	H44	5	0	1	1
Hotel Tainan	H45	7	0	1	0
The Westin Resort	H46	6	0	1	1

Note:
Room scale (number of rooms): 1: rooms>700, 2: 600<rooms<700, 3: 500<rooms<600, 4: 400<rooms<500,5: 300<rooms<400, 6: 200<rooms<300, 7: 100<rooms<200, 8: rooms<100.
Management style: 0: indepedent, 1: international chain; Location: 0: resort area,
Closeness to CKS (1 hour driving): 0: far, 1: closeness

Appendix B: Efficiencies of ITHs of the three-year windows during 1997-2002

	Time						Row		Std.	Column	Total		RTS		Frontier	
ITHs	1997	1998	1999	2000	2001	2002	average	Mean	Dev.	Range	Range	IRS	CRS	DRS	Freq.	Refs.
H01	0.434	0.451	0.569				0.485	0.542	5.88%	0.036	0.171	0	2	10	0	
		0.460	0.590	0.581			0.544									
			0.605	0.590	0.535		0.577									
				0.605	0.539	0.543	0.562									
H02	0.879	0.934	1.000				0.938	0.951	4.45%	0.043	0.121	0	0	12	4	15
		0.952	1.000	0.957			0.970									
			1.000	0.984	0.925		0.970									
				1.000	0.896	0.889	0.928									
H03	0.272	0.497	0.498				0.423	0.605	18.87%	0.210	0.728	0	0	12	1	0
		0.519	0.521	0.567			0.536									
			0.527	0.586	1.000		0.704									
				0.591	0.790	0.889	0.757									
H04	0.157	0.411	0.510				0.359	0.518	12.75%	0.090	0.499	0	0	12	0	
		0.455	0.553	0.567			0.525									
			0.596	0.642	0.550		0.596									
				0.657	0.555	0.569	0.594									
H05	0.786	0.706	0.740				0.744	0.751	3.45%	0.051	0.136	0	3	9	0	
		0.757	0.737	0.697			0.730									
			0.781	0.748	0.745		0.758									
				0.742	0.740	0.833	0.772									
H06	1.000	1.000	1.000				1.000	1.000	0.00%	0.000	0.000	2	10	0	12	1
		1.000	1.000	1.000			1.000									
			1.000	1.000	1.000		1.000									
				1.000	1.000	1.000	1.000									
H07	0.518	0.437	0.566				0.507	0.666	18.12%	0.124	0.563	0	1	11	2	1
		0.498	0.586	0.598			0.560									
			0.624	0.654	1.000		0.760									
				0.630	0.876	1.000	0.835									
H08	0.335	0.715	0.707				0.586	0.710	11.74%	0.067	0.493	0	0	12	0	
		0.743	0.735	0.761			0.746									
			0.744	0.776	0.717		0.746									
				0.828	0.733	0.728	0.763									
H09	1.000	0.624	0.693				0.772	0.836	12.96%	0.116	0.376	0	1	11	4	11
		0.695	0.750	1.000			0.815									
			0.810	1.000	0.817		0.876									
				1.000	0.817	0.830	0.882									
H10	0.758	0.824	1.000				0.861	0.910	9.22%	0.026	0.242	0	1	11	6	9
		0.850	1.000	1.000			0.950									
			1.000	1.000	0.832		0.944									
				1.000	0.830	0.827	0.886									
H11	0.251	0.568	0.631				0.483	0.609	13.02%	0.103	0.484	0	1	11	0	
		0.646	0.690	0.687			0.674									
			0.733	0.732	0.551		0.672									
				0.735	0.543	0.540	0.606									
H12	0.779	0.773	0.860				0.804	0.894	7.88%	0.075	0.227	0	0	12	2	21
		0.791	0.872	0.989			0.884									
			0.935	1.000	0.914		0.949									
				1.000	0.921	0.899	0.940									
H13	0.430	0.409	0.618				0.486	0.723	21.63%	0.038	0.591	0	7	5	3	3
		0.447	0.627	1.000			0.691									
			0.631	1.000	0.858		0.830									
				1.000	0.860	0.791	0.884									
H14	0.713	0.605	0.706				0.675	0.667	7.75%	0.025	0.307	0	1	11	0	
		0.625	0.681	0.665			0.657									
			0.681	0.665	0.773		0.706									
				0.653	0.771	0.466	0.630									
H15	0.458	0.377	0.433				0.423	0.498	5.96%	0.096	0.221	0	0	12	0	
		0.440	0.484	0.512			0.479									
			0.529	0.538	0.529		0.532									
				0.565	0.517	0.598	0.560									
H16	0.434	0.362	0.355				0.384	0.420	6.64%	0.015	0.187	0	7	5	0	
		0.371	0.363	0.393			0.376									
			0.369	0.402	0.542		0.438									
				0.408	0.541	0.499	0.483									

Note:
RTS: IRS denotes increasing returns to scale;
CRS denotes constant returns to scale;
DRS denotes decreasing returns to scale.
Std. Dev.: the standard deviation × 100.
Refs: the number of references to this ITH as a peer.

Appendix B Continued 1

ITHs	Time 1997	1998	1999	2000	2001	2002	Row average	Mean	Std. Dev.	Column Range	Total Range	RTS IRS	CRS	DRS	Frontier Freq.	Refs.
H17	1.000	0.805	0.872				0.892	0.929	7.57%	0.053	0.195	0	0	12	6	15
		0.820	0.863	1.000			0.894									
			0.917	1.000	1.000		0.972									
				1.000	1.000	0.869	0.956									
H18	1.000	0.979	1.000				0.993	0.968	5.28%	0.021	0.152	0	5	7	8	46
		1.000	1.000	1.000			1.000									
			1.000	1.000	0.893		0.964									
				1.000	0.896	0.848	0.915									
H19	1.000	0.855	0.834				0.896	0.888	9.01%	0.145	0.270	0	0	12	4	6
		1.000	0.848	0.890			0.913									
			0.907	1.000	0.795		0.901									
				1.000	0.799	0.730	0.843									
H20	1.000	1.000	1.000				1.000	0.984	3.09%	0.045	0.103	0	4	8	9	103
		1.000	0.955	1.000			0.985									
			0.956	1.000	1.000		0.985									
				1.000	1.000	0.897	0.966									
H21	1.000	1.000	1.000				1.000	0.878	21.16%	0.500	0.500	0	11	1	9	84
		0.536	0.500	1.000			0.679									
			0.500	1.000	1.000		0.833									
				1.000	1.000	1.000	1.000									
H22	1.000	0.982	1.000				0.994	0.986	2.81%	0.018	0.077	0	7	5	9	190
		1.000	1.000	1.000			1.000									
			1.000	1.000	0.923		0.974									
				1.000	0.926	1.000	0.975									
H23	0.777	1.000	1.000				0.926	0.955	7.20%	0.144	0.223	0	2	10	8	26
		1.000	0.856	1.000			0.952									
			0.892	1.000	1.000		0.964									
				1.000	0.934	1.000	0.978									
H24	0.451	0.485	0.434				0.456	0.495	2.85%	0.079	0.100	0	0	12	0	
		0.533	0.486	0.499			0.506									
			0.513	0.525	0.492		0.510									
				0.529	0.492	0.497	0.506									
H25	1.000	0.549	0.556				0.702	0.575	13.41%	0.043	0.533	0	1	11	1	0
		0.572	0.577	0.500			0.550									
			0.599	0.532	0.467		0.533									
				0.532	0.467	0.546	0.515									
H26	0.509	0.474	0.572				0.518	0.606	7.39%	0.063	0.233	0	1	11	0	
		0.492	0.606	0.634			0.577									
			0.635	0.664	0.707		0.669									
				0.649	0.663	0.670	0.661									
H27	0.508	0.649	0.630				0.596	0.627	4.38%	0.053	0.175	0	0	12	0	
		0.677	0.662	0.592			0.644									
			0.683	0.615	0.623		0.640									
				0.619	0.626	0.638	0.628									
H28	0.607	0.587	0.575				0.589	0.570	3.15%	0.028	0.093	0	1	11	0	
		0.609	0.594	0.562			0.588									
			0.603	0.571	0.516		0.563									
				0.572	0.518	0.533	0.541									
H29	0.476	0.576	0.593				0.548	0.561	0.25%	0.034	0.151	0	1	11	0	
		0.590	0.608	0.547			0.582									
			0.627	0.567	0.505		0.566									
				0.568	0.512	0.564	0.548									
H30	1.000	1.000	1.000				1.000	1.000	0.00%	0.000	0.000	1	10	1	12	21
		1.000	1.000	1.000			1.000									
			1.000	1.000	1.000		1.000									
				1.000	1.000	1.000	1.000									
H31	0.477	0.528	0.535				0.513	0.530	3.47%	0.074	0.131	0	0	12	0	
		0.570	0.555	0.490			0.539									
			0.608	0.532	0.507		0.549									
				0.537	0.511	0.505	0.517									
H32	0.523	0.683	0.652				0.619	0.634	6.98%	0.085	0.214	0	1	11	0	
		0.737	0.704	0.593			0.678									
			0.737	0.621	0.589		0.649									
				0.652	0.589	0.529	0.590									

Note:
RTS: IRS denotes increasing returns to scale;
CRS denotes constant returns to scale;
DRS denotes decreasing returns to scale.
Std. Dev.: the standard deviation × 100.
Refs: the number of references to this ITH as a peer.

Appendix B Continued 2

ITHs	Time 1997	1998	1999	2000	2001	2002	Row average	Mean	Std. Dev.	Column Range	Total Range	RTS IRS	CRS	DRS	Frontier Freq.	Refs.
H33	0.519	0.540	0.548				0.535	0.599	4.63%	0.069	0.147	0	0	12	0	
		0.565	0.582	0.594			0.581									
			0.617	0.634	0.637		0.629									
				0.645	0.646	0.666	0.652									
H34	0.688	1.000	0.630				0.773	0.701	9.43%	0.259	0.370	0	0	12	1	0
		0.741	0.642	0.667			0.683									
			0.666	0.689	0.651		0.668									
				0.689	0.660	0.687	0.679									
H35	1.000	0.396	0.313				0.570	0.732	31.80%	0.034	0.687	2	6	4	7	0
		0.414	0.316	1.000			0.577									
			0.347	1.000	1.000		0.782									
				1.000	1.000	1.000	1.000									
H36	0.512	0.483	0.508				0.501	0.525	2.29%	0.057	0.081	0	6	6	0	
		0.526	0.542	0.515			0.527									
			0.564	0.535	0.509		0.536									
				0.535	0.509	0.562	0.535									
H37	0.750	0.711	0.682				0.714	0.786	12.50%	0.020	0.318	0	4	8	3	11
		0.728	0.688	0.712			0.709									
			0.702	0.727	1.000		0.810									
				0.727	1.000	1.000	0.909									
H38	0.414	0.648	0.351				0.471	0.536	14.89%	0.085	0.395	0	4	8	0	
		0.712	0.407	0.406			0.508									
			0.436	0.436	0.714		0.529									
				0.436	0.719	0.747	0.634									
H39	1.000	1.000	1.000				1.000	0.989	3.81%	0.138	0.138	1	11	0	11	234
		1.000	1.000	1.000			1.000									
			1.000	1.000	1.000		1.000									
				1.000	0.862	1.000	0.954									
H40	0.584	0.547	0.638				0.590	0.615	3.39%	0.020	0.106	0	1	11	0	
		0.567	0.640	0.653			0.620									
			0.640	0.644	0.598		0.627									
				0.650	0.601	0.617	0.623									
H41	1.000	0.813	0.786				0.866	0.879	8.76%	0.214	0.223	0	3	9	4	74
		1.000	0.841	0.777			0.872									
			1.000	0.830	0.828		0.886									
				0.835	0.839	1.000	0.891									
H42	1.000	1.000	1.000				1.000	0.988	2.68%	0.083	0.083	0	8	4	10	227
		1.000	1.000	0.917			0.972									
			1.000	1.000	1.000		1.000									
				1.000	1.000	0.942	0.981									
H43	0.497	0.832	0.744				0.691	0.697	16.03%	0.049	0.537	0	5	7	1	22
		0.845	0.743	0.463			0.684									
			0.747	0.511	0.749		0.669									
				0.505	0.722	1.000	0.742									
H44	0.447	0.437	0.381				0.422	0.435	2.33%	0.052	0.101	0	2	10	0	
		0.482	0.425	0.416			0.441									
			0.433	0.425	0.450		0.436									
				0.425	0.450	0.446	0.440									
H45	1.000	0.776	0.824				0.867	0.880	8.85%	0.048	0.225	0	2	10	4	49
		0.775	0.809	1.000			0.861									
			0.856	1.000	0.846		0.901									
				1.000	0.854	0.816	0.890									
H46	0.706	0.614	0.683				0.667	0.738	9.16%	0.082	0.299	0	3	9	0	
		0.633	0.732	0.875			0.746									
			0.765	0.912	0.714		0.797									
				0.850	0.717	0.657	0.741									
Mean	0.688	0.696	0.711	0.760	0.755	0.758	0.730	0.730	0.085	0.081	0.265	6	133	413		
Std. Dev.	0.261	0.203	0.195	0.211	0.186	0.109						1%	24%	75%		

Note:
RTS: IRS denotes increasing returns to scale;
CRS denotes constant returns to scale;
DRS denotes decreasing returns to scale.
Std. Dev.: the standard deviation × 100.
Refs: the number of references to this ITH as a peer.