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The Efficiency of Nursing Homes in Taiwan: An Empirical Study Using Data Envelopment Analysis

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ABSTRACT

In this study, we measured and analyzed the production efficiency of nursing homes in Taiwan. The modified DEA (data envelopment analysis) technique was used in order to avoid the "censoring problem" caused by the traditional DEA method. We were able to investigate the impact of the performance of individual decision-making units on the estimated production frontier. We also identified the trade-off between quantity and quality outputs through comparing the efficiency measurements of different indexes. The non-parametric U test was used to verify these differences and the regression analysis to isolate possible contributing factors of the estimation results.

Keywords: nursing homes, technical efficiency, data envelopment analysis, long-term care

I. INTRODUCTION

The structure of population in Taiwan changes continuously in the recent decades. In 1993, the people with an age of more than 65 have reached a 7 % among the population. According to estimates of the Council for Economic Planning and Development, this ratio will even raise to 21.65% 30 years later (in 2036). The aging of the population and the transition of family function have become a major concern both in the public and academic worlds. In general, the elderly people face three kinds of common problems: (acute) medical care, income, and long-term care. Newer measures of social welfare have thus been directed to deal with these situations. For example, the National Health Insurance has provided a solution to the acute medical care of the aged. The various annuity programs and proposed National Pension Insurance shall solve, to a certain degree, the income problem of the aged. But, the long-term care, though not fully neglected, seems to receive less attention from the political side.

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Besides the traditional family care by the relatives, the long-term care of the elderly in need can be provided in both institutional settings (for example, nursing homes) and non-institutional settings (for example, home care from the nursing teams). However, the available services are quite limited currently in Taiwan. Although the government provides grants to officially accredited nursing homes, the tremendous excess demand has given rise to the prosperity of unaccredited nursing homes. The qualities of care provided by these private, unapproved nursing homes are diverse, most of the time unsatisfactory. In recent years, the government has thus helped promote these nursing homes into officially regulated institutions, instead of direct sanction.

An accredited nursing home must conform to the setup requirements, follow the operational guidelines, and receive periodic inspection from the governing authorities. How to increase the production efficiency and reduce the operational cost of nursing homes has been concerned by government regulated authorities and welfare economists. However, there is still a lack of an overall, systematic measurement among different nursing homes. Comparisons are usually made with simple ratio analysis only. In this study, we investigate and analyze the production efficiency of nursing homes in Taiwan in order to deliver further information as to their performance.

It is generally believed that the types of ownership influence the performance of production efficiency. It is also reasoned that the bureaucratic character, the rigidity of the decision-making process and financial structure, and the lack of profit-maximizing incentive (public inefficiency) have negative impacts on the production efficiency of publicly owned nursing homes. On the other side, the literature reveals that the non-price competition in the medical market can exert a positive impact on the production efficiency of publicly owned nursing homes. Furthermore, more resources are required in order either to elevate the quality of care or to lower the accident rate in nursing homes. When the quality of care is taken into consideration, the overall effects of different factors on the production efficiency of nursing homes remain unknown and deserve a detailed examination. There are indeed several studies about the productive performance of long-term care units (including nursing homes or residential homes). However, there are very few studies about the situation in Taiwan (Chou and Wang, 2000; Chen, 2002).

In our study, the empirical data coming from the "Performance Evaluation Report of Nursing Homes in Taiwan" which was accredited by experts, released by the Ministry of the Interior in 1995. We are particularly interested in the impacts of ownership, location, size and type of care.

With respect to the estimation techniques, there are two completely different approaches in the literature: the frontier parametric analysis and the frontier non-parametric analysis (Fried et al., 1993).[1] The former approach arbitrarily assumes that the production technology and efficiency follow some kind of parametric functions and statistical distributions, and regression[2] or mathematical programming[3] is used to estimate the production performance. The latter approach, or the so-called data envelopment analysis (DEA), doesn't have any specific assumptions about the production technology; it uses the observed input-output information and the mathematical programming technique to estimate the production technology. It is generally deemed that if a priori information about the production technology is not available, an arbitrary assumption about the parametric form of production technology may distort the estimates. Thus, we adopt the frontier non-parametric analysis in our study. Besides, we utilize the modified DEA technique in our estimation in order to avoid the "censoring problem" caused by the traditional DEA method.[4] Different from the traditional DEA methods, the values of units are not confined in the modified DEA; therefore, we are able to investigate the impact of individual decision-making units (DMUs) on the estimated production frontier. Finally, we can use OLS (ordinary least squares) regressions to identify factors that have the most contributions to the efficiency performance.

[1]. For non-frontier analyses, see Hopper (1965); and Lau and Yotopoulos (1971).

[2] For example, Perelman and Pestieau (1988) used a corrected least square technique to estimate the production frontier.

[3] For example, Aigner and Chu (1968) assumed that the production technology could be represented as a sort of the Cobb-Douglas function, and used a linear programming technique to estimate the production function (the so-called goal programming technique). Albriktsen and Førsund (1990) used the same assumptions in their study. Besides, Nishimizu and Page (1982) assumed that the production technology could be represented as a translog function, and used a linear programming technique to estimate their production function.

[4]. The "modified" DEA method modifies the reference sets used by the traditional DEA method and is able to compare the differences between efficient DMUs. See the discussion of section **ESTIMATION MODEL** for details.

The remainder of this paper proceeds as follows. First, the literature about efficiency of nursing homes will be systematically reviewed; second, a theoretical foundation of our estimation will be presented; third, the data are discussed; finally, the paper concludes with thorough discussion of the research results.

II. LITERATURE REVIEW

1. Efficiency of Nursing Homes

Measuring the production efficiency of nursing homes has been a research focus of economists and sociologists for a long time.[5] Among the literatures addressed to this topic, the quality of care and the case-mix of residents take the spotlight of attention.

It is generally recognized that there is a negative relationship between quality of care and efficiency of nursing homes (Nyman and Bricker, 1989; Sexton et al., 1989; Nyman et al., 1990; Fizel and Nunnikhoven, 1992; Chattopadhyay and Heffley, 1994; Kooreman, 1994). However, Deming (1994) believed that there should be a negative relationship between quality and cost in the long run. If the quality was high, the confidence of the customer would be stronger and the cost could become lower. In this way, quality and efficiency could reinforce each other. Other scholars agreed to some extent that the positive relationship between efficiency and quality existed only in non-for-profit nursing homes, but not in for-profit nursing homes (Nyman and Bricker, 1989; Kleinsorge and Karney, 1992). Therefore, the quality of care should play a significant role in the estimation.

As to measuring the quality of nursing homes, Linn (1974) used the evaluation by professional reviewing groups, while Ruschlin & Levey (1972) and

[5] Efficiency can be divided as:
(1)Technical efficiency: the comparison of the optimal input-output combination and the actual input-output combination;
(2)Economic efficiency: given proper behavior assumption of DMUs; for example, cost-minimization, revenue-maximization or profit-maximization, the cost frontier, revenue frontier, or profit frontier can be defined. The economic efficiency is obtained by comparing the optimal cost, revenue, or profit with the actual cost, revenue, or profit. Thus, technical efficiency is a necessary condition of economic efficiency.
In nursing home industry, the research topic on cost inefficiency is popular (Hofler and Rungeling, 1994; Skinner, 1994; Vitaliano and Toren, 1994; Eggink and Blank, 2000, 2001). But in Taiwan, it is hard to find cost data for nursing homes; the paper focuses on the technical efficiency.

Walsh (1979) used the variable of self-financed residents. McKay (1988) took the number of nursing hours per patient-day as the measurement. Nyman(1988) and Nyman and Bricker (1989) used the number of violations of the Medicaid Certification Code as the quality measurement. Fizel and Nunnikhoven (1992) used evaluation reports and empty beds as quality indexes. Kleinsorge and Karney (1992) used the occupancy rate and the number of residents with decubiti to measure the quality of care. Kooreman (1994) used indicators such as: whether a nursing home has resident and/or family member committees, the dispute handling process, and visiting hours as indexes to the quality. Sainfort et al. (1995) used mortality rate, hospitalization rate, pressure ulcer rate, functional status change, accident rate, incontinence, weight loss, inflection, restraint use, catheter use rate, discharge rate, staff turnover etc.

Owing to the nature of being labor-intensive in the nursing home industry, the labor input was one of major concerns among all the discussions. Generally speaking, the amount of labor inputs depended on the case-mix of residents. More complicated the case-mix was, more inputs were needed and a low efficiency performance could be expected (Nyman and Bricker, 1989; Nyman et al., 1990; Fizel and Nunnikhoven, 1992; Chattopadhyay and Heffley, 1994; Dusansky and Wilson, 1994; Kooreman, 1994). Therefore, the case-mix of nursing homes should be seriously taken into consideration in the estimation (Bjorkgren et al., 2001; Fried et al., 1999; and Fried et al., 2002).

There were different indexes that were used as the measurement of the case-mix. The average patient-day was used by Nyman and Bricker (1989) and Kooreman (1994). The age structure of residents was used by Nyman and Bricker (1989), Nyman et al. (1990), Dusansky and Wilson (1994), and Kooreman (1994). The level of dependence, or the ADL (activities of daily living) index, was used by Nyman and Bricker (1989), Nyman et al. (1990), Fizel and Nunnikhoven (1992), Chattopadhyay and Heffley (1994), Dusansky and Wilson (1994, 1995). The institutional classification was used by Chattopadhyay and Heffley (1994). And the numbers of patients with decubiti, disability, dementia, and long-term medication were used by Nyman et al. (1990).

In addition to the quality and case-mix, other factors that might influence the efficiency included: (1). the scale of nursing homes (Chattopadhyay and Ray, 1996;

Filippini, 2001); (2). ownership; (3). Affiliation;[6] (4). percentage of self-financed residents or government-financed residents (Nyman and Bricker, 1989; Nyman et al., 1990; Fizel and Nunnikhoven, 1992; Chattopadhyay and Heffley, 1994);[7] and (5). type of institution (Dusansky and Wilson, 1995); (6) market concentration (Wilson and Jadlow, 1982; Nyman and Bricker, 1989).

2. The Measurement of Production Efficiency

The "classic" use of DEA as a measurement of efficiency involved a two-stage process. In the first stage, only factors that could be quantified and controlled by the decision-makers were included into the estimation of production frontier. The regression analysis in the second stage included the factors that could not be quantified, but might influence the efficiency performance. Some environmental variables such as ownership belonged to this group of factors (Fried et al., 1993). Both the traditional DEA method and the modified DEA method (Andersen, and Petersen, 1993) had been used in the first stage estimation. The major difference between the traditional and modified ones is that the estimation results with the latter method are not censored to the value of unity. Thus, instead of the censored Tobit regression analysis in traditional DEA (Dusansky and Wilson, 1994; Kooreman, 1994), the OLS regression is used in the second stage if the modified DEA is adopted. Most of the literature on the efficiency of nursing home employed this "classic" two-stage process (Nyman and Bricker, 1989; Nyman et al., 1990; Fizel and Nnnikhoven, 1992; Kooreman, 1994).[8]

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[6] Kooreman (1994) thought that nursing homes that were affiliated with hospitals could increase efficiency by exchange of resources; however, Nyman and Bricker (1989) thought that nursing homes might lose efficiency because the managers of hospitals were not necessarily familiar with the operation of nursing homes.

[7]. Generally speaking, nursing homes with a higher percentage of Medicaid residents were usually accompanied with lower quality of care. There were two possible explanations for this situation. First, nursing homes with a lower percentage of Medicaid residents received fewer fees from Medicaid than from self-financed residents; in turn, it could limit the incentives of nursing homes to provide better care (Lewis et al., 1985; Weissert and Scanlon, 1985). Second, Kosberg (1973) and Scanlon (1979) believed that the existence of excess demands "encouraged" nursing homes to give priority to self-financed patients. The Medicaid patient could not help but accept a lower quality of care in order to get admitted to a nursing home. By examining the 1979 Wisconsin Data, Scanlon (1980) found that the excess demand of nursing homes was the major cause of this negative relationship between quality of care and percentage of Medicaid residents.

[8] Fried et al. (1999) and Fried et al. (2002) used four-stage DEA and three-stage DEA, respectively. But the two-stage DEA model is still popular.

In this study, we followed the standard two-stage process. A modified DEA method was used to estimate the efficiency of nursing homes in Taiwan. One of the benefits of the modified DEA method is the possibility of investigating the impact of the individual DMUs on the estimated production frontier. Another feature of our study was that we formed several combinations of input-output data. Then, the estimations that took consideration of quality were compared to those without quality.

III. ESTIMATION MODEL

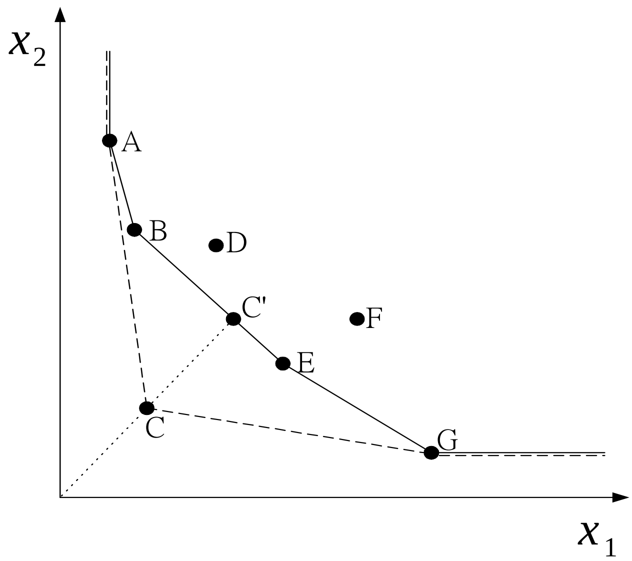
The DEA method utilizes the mathematical technique of linear programming to estimate the production frontier that envelops all the observed input-output vectors of selected DMUs. Its feature is that no parametric assumption about the production technology is required. It is only assumed that the production possibility set is convex. The estimated frontier is a “relative” production frontier based upon all the chosen DMUs. A DMU is “relative” efficient if its input-output vector is located at the estimated frontier, otherwise it is “relative” inefficient if located at the inner of or below the estimated frontier. Having the pioneering works of Debreu (1951) and Farrell (1957) as models, Charnes, Cooper and Rhodes (1978, abbreviated as CCR in the following) modified and expanded the Debreu-Farrell production efficiency measurement. Banker et al. (1984) relaxed the assumption of CCR model in the constant return to scale technology, and took into account the situations of non-constant return to scales.

Given there are *K* inputs, *M* outputs, and *N* DMUs. x_i is a $(K \times 1)$ column vector representing the inputs of the i^{th} DMU and u_i is a $(M \times 1)$ column vector representing the outputs of the i^{th} DMU. $X_{(K \times N)} = [x_1, ..., x_N]$, $X_{(i)} = [x_j], \ \forall j \neq i$; $U_{(M \times N)} = [u_1, ..., u_N]$, $U_{(i)} = [u_j], \ \forall j \neq i$. The production technology can be represented as $S = \{(x, u), \ x \text{ can produce } u\}$.

In measuring the efficiency score of the i^{th} DMU with the modified DEA method, the reference set includes all other input-output vectors of DMUs than the i^{th} DMU itself.[9] Thus, the efficiency score is not restricted to the value of unity.

[9]. In the traditional DEA method that measures the efficiency score of the i^{th} DMU, the reference set includes all other input-output vectors of DMUs, also the i^{th} DMU itself.

Figure 1 illustrates this situation. From figure 1, X_1 and X_2 are the inputs 1 and input 2 of the firms. **A, B, C, D, E, F, G** are the decision-making units, and **C'** denotes the linear combination point of **B** and **E.** The technical effieiency score of point C in Figure 1 is OC'/OC.



Dashed line: The estimated frontier of the traditional DEA method;
Real line: The estimated frontier of the modified DEA method.

Figure 1. The modified DEA method

According to Andersen and Petersen (1993), the estimated efficiency score of the i^{th} DMU with the modified DEA method can be expressed as: [10]

$$\min\{\lambda_i^* \mid \lambda_i^* x_i \geq X_{(i)} q_i^*,\ \ u_i \leq U_{(i)} q_i^*,\ \ q_i^* \in \Re_+^N\} \quad \textbf{(1)}$$

$\lambda_i^* \geq 1$ means that the i^{th} DMU is relatively efficient in comparison with other DMUs in the data set; and the larger the value is, the better the efficiency performance is.[11] The efficiency score is estimated under the assumption that the

[10] The same concept was applied to modified Free Disposal Hull (FDH), please refer to Puyenbroeck (1998).

[11] The relationship of the estimated λ_i value with the traditional DEA method and the λ_i^* value with the modified DEA method can be represented as: if $\lambda_i^* < 1$, then $\lambda_i = \lambda_i^* < 1$, and the production performance of the i^{th} DMU is inefficient; for $\lambda_i^* \geq 1$, then $\lambda_i = 1$, and the production performance of the i^{th} DMU is efficient.

production technology has constant returns to scale (CRS) in (1).[12] I is denoted as a $(1\times N)$ row vector of 1s, and q_i as a $(N\times 1)$ column vector of intensity variable. After adding another constraint $Iq_i = 1$ to (1), the production technology becomes the type of variable returns to scale (VRS) and the estimated efficency score requires no assumption of returns to scale.[13,14] However, when the i^{th} DMU is excluded in estimating its efficiency score, the frontier may be altered and it becomes infeasible to measure the radial efficiency of the i^{th} DMU under VRS. We could describe the infeasible problem from figure 2. **A, B, C** are the decision-making unit which use one input x to produce one output u. Obviously, the efficiency of point **A** and **B** could be measured by input-oriented modified DEA, but point **C** couldn't.[15] This problem will not exist if the constant returns to scale are assumed.

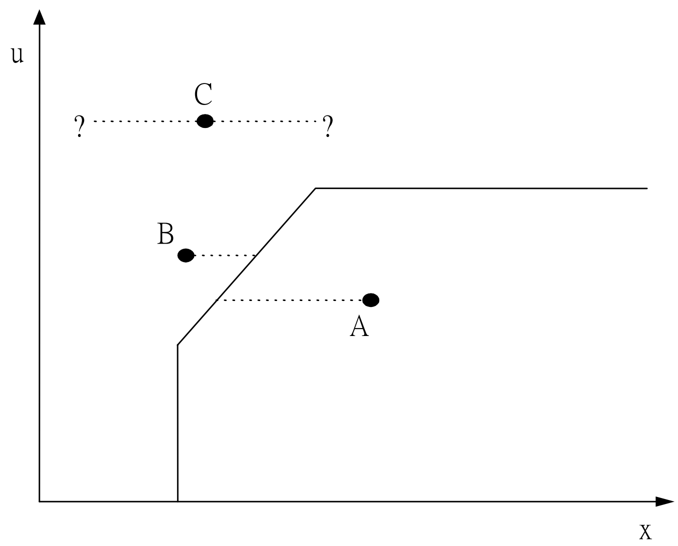


Figure 2. The infeasible problem

[12] There is no restriction to q_i in (1).

[13] VRS means that the production is composed of possible CRS, IRS (increasing returns to scale) and DRS (decreasing returns to scale) production technology.

[14] $Iq_i \le 1$ denotes that the technology is non-increasing return to scale (NIRS).

[15] **DMU A** is inefficient because it locates below the estimated frontier. **DMU B** is super-efficient because it locates above the estimated frontier.

From the above discussion, we know that the modified DEA method can avoid the censoring problem existing in the traditional DEA method. Thus, it is possible to understand the influences of individual DMUs upon the frontier to be estimated. Wilson (1995) has also taken this advantage to identify possible outliers.

To include the quality of care into the estimation model, we denote a_i as the $(H \times 1)$ column vector representing the quality characters of the i^{th} DMU, and $A_{(H\times N)} = [a_1, \ldots, a_N]$, $A_{(i)} = [a_j]$ $\forall j \neq i$. Then, the production technology can be represented as $S = \{(x, u, a),\ x \text{ can produce } u, a\}$. Based on the framework of Färe et al. (1995), the efficiency score of the i^{th} DMU can be represented as:

$$\min\{\lambda_i^* \mid \lambda_i^* x_i \geq X_{(i)} q_i^*, u_i \leq U_{(i)} q_i^*, a_i \leq A_{(i)} q_i^*, q_i^* \in \Re_+^N\} \qquad \textbf{(2)}$$

(2) is the programming that we use to estimate the efficiency scores of nursing homes in the following discussions.

IV. DATA DESCRIPTIONS

The empirical data in this study came from the "Performance Evaluation Report of Nursing Homes in Taiwan" released by the Ministry of the Interior in 1995. According to the report, 53 LTC institutions were officially accredited in that year and had a total capacity of 12,482 patients.

The inputs for analysis were: 1. planned capacity of residents (the number of beds), 2. the number of administrative staff, 3. the number of other medical personnel (all medical staffs except doctors and certificate nurses), 4. the number of doctors, 5. the number of registered nurses, 6. the number of physical therapists, 7. the number of pharmacists, and 8. the number of dietitians. The outputs in the estimation could be divided into two categories: one was the quantity output, and the other is the quality output. The quantity output was measured by the number of actual residents. The quality outputs were obtained from accreditation of the professional review committee, including: administrative service performance,[16]

[16] The evaluation items included administrative management, the operation of funding, and personnel utilization.

life care performance,[17] health care performance,[18] and accident rate.[19]

With respect to the ownership, there were 16 publicly owned nursing homes (30.2%), providing 7,615 beds in total (61%) with an average of 476 beds per institution. The other 37 private nursing homes (69.8%) provided 4,867 beds in total (39%) with an average of 132 beds per institution. It was apparent that a publicly owned nursing home had in average more beds (3.6 times) than a private nursing home. As to the average values of variables that we were interested in, all the inputs and outputs of publicly owned nursing homes were larger than private nursing homes, except those of the average health care performance and accident rate. It was worth noting that the quality outputs of private nursing homes had larger standard deviations than those of publicly owned nursing homes. It implied that the quality of care among private institutions were more diverse.

With respect to the types of services provided,[20] there were 12 (22.7%) nursing homes offering only medical care, with 933 (7.5%) beds in total and 78 beds per institution in average. 28 (52.8%) nursing homes offered only life care, with 5,511 (44.2%) beds in total and 197 beds per institution in average. And the other 13 (24.5%) nursing homes offered both medical and life care, with 6,038 (48.3%) beds in total and 465 beds per institution in average. In terms of the number of beds, those nursing homes which provided both medical and life care were larger in average. All the inputs and outputs of these institutions were the largest except the number of nurses and the accident rate,. In the 28 nursing homes that provided life care only, all the average values of inputs and standard values were smallest, and so was the accident rate. In the 12 nursing homes that

[17] The evaluation items included daily life services, placement and professional counseling, environment and facilities, recreational services, residents' participation in general affairs, and other life aids.

[18] The evaluation items included the service situation of doctors, nurses, pharmacists and physical therapists, the health facilities and medical equipment and their utilization rate, and the completeness of records, and referral networks.

[19] The accident rates were measured by the ratio of the number of accidents over the number of residents times 100%. A smaller value implied that more inputs were used to prevent accidents and thus there was a higher quality of care. To use this ratio as an output measurement, we took the value of (100% - the accident rate) instead in the calculation.

[20] The nursing homes with only medical care provided services to patients who cannot handle daily living and require medical aids. The nursing homes with only life care provided services to patients who can handle daily living. Different kind of nursing homes above means different case-mix.

provided medical care only, the average value of nurses, the health care performance, and the accident rate were the highest.

With respect to the governing authorities,[21] there were 11 (20.8%) nursing homes supervised by the municipal governments (2 by the Kaohsiung City Government and 9 by the Taipei City Government) with 3,293 (26.4%) beds in total and 299 beds per institution in average. The Taiwan Provincial Government supervised 19 (35.8%) nursing homes with 5,416 (43.4%) beds in total and 197 beds per institution in average. And the county governments supervised the other 23 (43.4%) nursing homes with 3,773 (30.2%) beds in total and 164 beds per institution in average. It was known that in terms of the number of beds provided by the nursing homes, the size of municipally supervised nursing homes were larger, about 2 times and 1.5 times, than those of county- and provincially supervised nursing homes. The number of administrative staffs and the number of other medical personnel in the municipally supervised nursing homes were smaller than those in the provincially supervised nursing homes; however, the number of the actual residents was larger. The county-supervised nursing homes had fewer actual residents and smaller input than the municipally and provincially regulated nursing homes. Because half of the municipally supervised nursing homes were those which provided medical care only, their average accident rate and average performance of health care were the largest.

With respect to the size of nursing homes,[22] there were 10 (18.9%) large-sized nursing homes with 6,850 (54.9%) beds in total and 685 beds per institution in average. 19 (35.8%) medium-sized nursing homes provided 4,521 (36.2%) beds in total with 238 beds per institution in average. And the other 24 (45.3%) small-sized nursing homes provided 1,111 (8.9%) beds in total with 46 beds per institution in average. Among the large-sized nursing homes, 8 were publicly owned and their average values of all inputs and outputs were the largest except the number of dietitians. The small-sized nursing homes were rather homogenous

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[21] The different governing authorities have different financial subsidies to nursing homes, for example, Taipei (or Kaohsiung) vs. county-supervised, so the operational performance of the homes are affected.

[22] We defined the small-, medium- and large-sized nursing homes by the number of beds provided. The small-sized nursing homes were those that provided beds less than 100, the medium-sized nursing homes provided beds between 100 to 499, and the large-sized nursing homes provided beds no less than 500.

with respect to inputs. The administrative and life care performances of large-sized nursing homes were better than medium- and small-sized ones, but the health care performance and accident rate of small-sized nursing homes were larger, though with greater variations.

In consideration of the deterministic nature of the DEA method, we proposed 4 different combinations to avoid the problems of sensitivity.[23]

The first combination (MIX1):

Outputs: actual residents;

Inputs: the number of doctors, the number of registered nurses, the number of physical therapists, the number of pharmacists, the number of dietitians, the number of administrative staff, and the number of beds.

The second combination (MIX2):

Outputs: actual residents;

Inputs: the number of doctors, the number of registered nurses, the number of other personnel, and the number of beds.

The third combination (MIX1Q):

Outputs: actual residents, administrative service performance, life care performance, health care performance, and accident rate;

Inputs: the number of doctors, the number of registered nurses, the number of physical therapists, the number of pharmacists, the number of dietitians, the number of administrative staff, and the number of beds.

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[23] In general, the variations of sensitivity had three possible reasons: (1) the input-output combinations selected by researchers; (2) the existence of outliers; and (3) the stochastic nature embedded in the operation of industries. Some solutions had been proposed in the literature. For the first case, researchers used several combinations of inputs and outputs to see whether the results were consistent (Valdmanis, 1992). For the second case, the identification of outliers was a possible solution (Wilson, 1995). For the last case, Sengupta (1987) proposed the stochastic DEA method, Land et al. (1994) suggested the Chance Constrained DEA method, and some other scholars, for example, Wilson and Simar (1995), combined the bootstrap and DEA method to investigate the problem of sensitivity.

The fourth combination (MIX2Q):

Outputs: actual residents, administrative service performance, life care performance, health care performance, and accident rate;

Inputs: the number of doctors, the number of registered nurses, the number of other personnel, and the number of beds.

What the combination MIX1 differed from MIX2 was that the total number of physical therapists, pharmacists, dietitians, and administrative staff in MIX1 was equivalent to the variable “other personnel” in MIX2. The inputs of MIX1Q and MIX2Q were the same as those of MIX1 and MIX2 respectively; however, quality measurements were added into outputs of MIX1Q and MIX2Q. Thus, the impacts of summing inputs and the effects of including quality measurements could be studied.

V. EMPIRICAL RESULTS

The efficiency scores of the 53 nursing homes were listed in Table 1 after estimation with the modified DEA method. For all the 4 combinations, fewer than half of the nursing homes in the study were efficient (MIX1: 19; MIX2: 10; MIX1Q: 25; MIX2Q: 22); it implied that there were rooms for improvements.[24] As we mentioned in Section III, the infeasible problems occurred when the efficiency scores were estimated under the assumption of variable returns to scale technologies. In the following discussions, we narrowed our focus to the cases of constant return to scale.

[24] From the perspective of the mathematical programming technique, too many inputs and outputs (variables) in the DEA-type methods would increase constraints and “shrink” the feasible set at the same time. The possibility of an efficient DMU would become greater so that a direct comparison of the efficient scores generated by the 4 combinations seemed to be of less significance.

Table 1. The efficiency scores of individual DMUs - estimated by the modified DEA method

	MIX1		MIX2		MIX1Q		MIX2Q	
	CRS	*VRS*	*CRS*	*VRS*	*CRS*	*VRS*	*CRS*	*VRS*
DMU1	0.9365	0.9365	0.9273	0.9299	0.9365	1.0740	0.9273	1.0195
DMU2	0.8679	1.1849	0.8678	0.9749	0.8679	-	0.8678	2.4019
DMU3	1.0000	1.3245	0.9893	0.9971	1.6587	-	0.9994	1.0271
DMU4	0.7750	0.9070	0.7747	0.9070	0.9401	3.5717	0.9360	3.1126
DMU5	1.0034	2.3256	1.0034	2.3256	1.0034	-	1.0034	-
DMU6	0.8740	0.9844	0.8717	0.9844	0.8740	-	0.8717	-
DMU7	1.0000	1.4498	0.9889	1.4498	1.6612	1.8538	1.6323	1.7883
DMU8	1.1932	1.2281	1.1185	1.1263	1.1932	1.2466	1.1271	1.1284
DMU9	0.9648	1.3590	0.9648	1.2532	0.9648	-	0.9648	2.7625
DMU10	0.8739	0.8795	0.8739	0.8795	0.8958	-	0.8958	-
DMU11	1.0000	1.0000	0.9881	0.9961	1.0000	1.0000	0.9952	0.9963
DMU12	1.0000	1.0000	0.9849	0.9938	1.0000	1.0000	0.9946	0.9958
DMU13	0.5714	1.6000	0.5714	1.6000	1.8592	-	1.8592	-
DMU14	1.0757	1.1079	1.0757	1.1079	1.1187	2.7522	1.1187	2.7522
DMU15	1.0000	1.0000	0.9849	0.9972	1.0180	1.5857	1.0151	1.5705
DMU16	0.9158	0.9256	0.9148	0.9198	0.9290	1.2628	0.9225	1.1465
DMU17	0.8347	-	0.8340	-	0.8347	-	0.8340	-
DMU18	1.7218	-	1.7218	2.4120	1.7218	-	1.7218	4.0142
DMU19	1.0000	1.0000	0.9849	0.9903	1.0008	1.0374	1.0002	1.0036
DMU20	0.6000	0.7534	0.5909	0.7534	0.8555	1.6539	0.8555	1.6539
DMU21	0.8663	0.9750	0.8663	0.9750	0.9797	1.0723	0.9797	1.0723
DMU22	0.7143	1.0255	0.7124	0.9751	1.0550	1.6629	1.0536	1.6629
DMU23	1.0549	-	1.0549	-	1.0549	-	1.0549	-
DMU24	0.9458	1.5472	0.9458	1.1734	0.9458	-	0.9458	2.1091
DMU25	1.0316	-	1.0316	-	1.0316	-	1.0316	-
DMU26	0.1818	0.5325	0.1813	0.5300	0.5455	0.5921	0.5455	0.5907
DMU27	0.3799	0.4003	0.3799	0.4003	0.4037	3.0000	0.4037	3.0000
DMU28	0.4247	0.4367	0.4173	0.4286	0.4398	1.0503	0.4316	0.9076
DMU29	0.5110	0.5764	0.5110	0.5764	0.5801	0.9721	0.5801	0.9721
DMU30	1.0154	1.0154	1.0154	1.0154	1.0512	-	1.0374	-
DMU31	0.8296	0.8296	0.8256	0.8262	0.8296	-	0.8269	-

Table 1. The efficiency scores of individual DMUs - estimated by the modified DEA method (continued)

	MIX1		MIX2		MIX1Q		MIX2Q	
	CRS	*VRS*	*CRS*	*VRS*	*CRS*	*VRS*	*CRS*	*VRS*
DMU32	0.7248	0.9518	0.7248	0.8628	0.7248	0.9934	0.7248	0.8665
DMU33	0.4289	0.5399	0.4288	0.4924	0.5465	0.5642	0.5186	0.5376
DMU34	1.0835	1.1485	1.0835	1.1485	1.0835	1.2487	1.0835	1.1772
DMU35	0.2163	0.3487	0.2163	0.3487	0.3621	0.6293	0.3621	0.6293
DMU36	0.6059	0.6078	0.6039	0.6078	0.6059	-	0.6039	-
DMU37	0.8000	1.0807	0.7991	1.0807	1.0952	1.1364	1.0848	1.1191
DMU38	0.9004	2.4591	0.9004	2.4591	2.4591	2.4591	2.4591	2.4591
DMU39	1.1989	1.2102	1.1989	1.2102	1.2124	-	1.2124	-
DMU40	0.9282	1.0571	0.9282	1.0571	1.0729	-	1.0729	-
DMU41	0.6829	0.8258	0.6827	0.8258	0.8445	0.9739	0.8354	0.8791
DMU42	1.0000	1.1333	0.9849	1.1333	1.2710	-	1.2710	2.6123
DMU43	0.6566	0.6574	0.6565	0.6574	0.6566	-	0.6565	-
DMU44	0.6786	0.6792	0.6786	0.6792	0.6808	-	0.6808	3.0604
DMU45	1.0000	1.1042	0.9999	1.0727	1.1141	1.4771	1.0904	1.2254
DMU46	1.4438	-	1.4438	-	1.4438	-	1.4438	-
DMU47	0.9823	0.9881	0.9823	0.9881	0.9884	-	0.9884	-
DMU48	0.9159	0.9187	0.9149	0.9179	0.9201	-	0.9198	-
DMU49	0.6250	0.6535	0.6247	0.6530	0.6615	0.6716	0.6600	0.6627
DMU50	0.8946	1.0674	0.8930	0.8935	0.8946	2.9431	0.8931	1.1634
DMU51	0.9307	1.1109	0.9307	1.1109	1.1127	1.3033	1.1127	1.3033
DMU52	1.0000	1.0000	0.9849	0.9922	1.0091	-	1.0077	4.8631
DMU53	0.7674	0.7840	0.7670	0.7749	0.7674	-	0.7670	2.7094
Numbers of efficient DMUs	19	30	10	21	25	46	22	43
Infeasible	0	5	0	4	0	25	0	16

Note1: ***CRS*** means constant returns to scale; ***VRS*** means variable returns to scale; **DMU** means decision-making unit.

Note2: **MIX1**-Outputs: actual residents; Inputs: the number of doctors, the number of registered nurses, the number of physical therapists, the number of pharmacists, the number of dietitians, the number of administrative staff, and the number of beds.

MIX2-Outputs of MIX1; Inputs: the number of doctors, the number of registered nurses, the number of other personnel, and the number of beds.

MIX1Q-Outputs of MIX1 + administrative service performance, life care performance, health care performance, and accident rate; Inputs of MIX1.

MIX2Q-Outputs of MIX2 + administrative service performance, life care performance, health care performance, and accident rate; Inputs of MIX2.

In Table 2, the means and standard deviations by characteristics of nursing homes were listed. Without consideration of quality of care (MIX1 and MIX2), publicly owned nursing homes had in average better performance than private nursing homes. But there would be almost no differences between the two groups when the quality of care was taken into account (MIX1Q and MIX2Q).

With respect to the types of services, nursing homes that provided only medical care performed consistently better than other nursing homes, no matter whether the quality of care was included. Without consideration of quality of care, nursing homes that provided only life care performed almost the same as those that provided both medical and life care. But the former would be better than the latter and almost equal to nursing homes that provided only medical care, after the quality of care was taken into account.

With respect to the governing authorities, municipally supervised nursing homes performed consistently better than other nursing homes. Without consideration of quality of cares, county-supervised and provincially supervised nursing homes performed almost the same. But the former performed better than the latter significantly when the quality of care was taken into account.

With respect to the size of nursing homes, the large-sized nursing homes performed as the best and the medium-sized and small-sized nursing homes performed almost the same when the quality of care was not included. However, when the quality of care was included, the small-sized nursing homes performed better than the large-sized and medium-sized nursing homes.

Table 2. Means & standard deviations of efficiency scores by characteristics

	MIX1	MIX2	MIX1Q	MIX2Q
OWNERSHIP:				
Public (n=16)				
Mean	0.91097	0.90587	0.99563	0.99107
Standard Deviation	0.30258	0.29866	0.36821	0.36646
Private (n=37)				
Mean	0.83926	0.83533	0.99587	0.97364
Standard Deviation	0.25607	0.25477	0.37689	0.35948
TYPES OF SERVICES: Services:				
Life Care (n=28)				
Mean	0.83367	0.83069	1.01682	1.01086
Standard Deviation	0.26851	0.26521	0.40142	0.40173
Medical Care (n=12)				
Mean	0.91631	0.90619	1.07467	1.01587
Standard Deviation	0.15204	0.14872	0.31209	0.24599
Both (n=13)				
Mean	0.86843	0.86673	0.87771	0.87595
Standard Deviation	0.35731	0.35801	0.34842	0.34929
SUPERVISORS:				
Cities (n=11)				
Mean	1.06081	1.04668	1.18371	1.11324
Standard Deviation	0.23495	0.23386	0.33027	0.28806
Province (n=19)				
Mean	0.80290	0.80194	0.84666	0.84163
Standard Deviation	0.24442	0.24508	0.24231	0.24306
Counties (n=23)				
Mean	0.81322	0.81090	1.02912	1.02806
Standard Deviation	0.27037	0.26967	0.43501	0.43509
SCALES:				
Large-sized (n=10)				
Mean	0.91292	0.91184	0.91443	0.91327
Standard Deviation	0.32843	0.32972	0.32596	0.32737
Medium-sized (n=19)				
Mean	0.84799	0.84312	0.86547	0.86076
Standard Deviation	0.30444	0.30012	0.28238	0.27845
Small-sized (n=24)				
Mean	0.84946	0.84431	1.13287	1.09978
Standard Deviation	0.22056	0.21798	0.41262	0.39841

In the above discussions only the average efficiency scores were compared and the direction of the differences of nursing homes highlighted. In the following, we used the statistical non-parametric U and K-W tests to inspect these differences.[25] The null hypothesis was that there were no differences for the groups of efficiency scores to be tested, and the alternative hypothesis was that there were differences for the groups of efficiency scores to be tested (The level significance is 0.05). The results were presented in Table 3.

At first, we tested the difference between groups of efficiency scores both when the quality of care was taken into account and when it was not. The results suggested that the difference was significant. Thus, separate comparisons of efficiency scores with and without quality of care were necessary.

As we could see from Table 3, the differences in efficiency scores between publicly owned and private nursing homes were insignificant no matter whether the quality of care was considered. The differences between nursing homes that provided different kinds of services were insignificant when the quality of care was not included in the estimation models, but they became significant when the quality of care was included. The differences in efficiency scores between nursing homes supervised by different governing authorities were insignificant no matter whether the quality of care was considered. Finally, the differences between nursing homes of different sizes were insignificant when the quality of care was not included in the estimation models, but they became significant when the quality of care was included.

Table 3. Results of test statistics and their significance of non-parametric tests

	With or Without Quality Consideration (U Test)			
MIX1 v.s. MIX1Q	1.9789**			
MIX2 v.s. MIX2Q	1.9748**			
	Ownership (U Test)	Type of Service (K-W Test)	Supervisor (K-W Test)	Size (K-W Test)
MIX1	0.6021	2.2592	9.2017**	0.0580
MIX2	0.5815	2.2334	8.9675**	0.0770
MIX1Q	-0.1550	5.3124*	7.6751*	7.7013**
MIX2Q	-0.0581	5.1789*	7.0533*	6.9549**

Note: Critical point of U test: $z_{\alpha} = z_{0.1} = 1.282$, $z_{0.05} = 1.645$; Critical point of K-W test: $\chi^2_{(\alpha,DF)} = \chi^2_{(0.1,2)} = 4.605$, $\chi^2_{(0.05,2)} = 5.991$.

Additionally, we used the OLS regression to identify factors that might

[25] We used the U test for testing the difference between two groups of efficiency scores (for example, publicly owned nursing homes and private nursing homes) and the K-W test for testing more than two groups (large-sized, median-sized, and small-sized nursing homes). See Sachs (1994).

influence the efficiency scores. Dummy variables represented the characteristics respectively:

OWNER: 1 denoted a public-owned nursing home; otherwise the value was 0;

HOME1: 1 denoted nursing homes that provided only medical care; otherwise the value was 0;

HOME2: 1 denoted nursing homes that provided both medical and life care, otherwise the value was 0;26

LOC1: 1 denoted municipally supervised nursing homes; otherwise the value was 0;

LOC2: 1 denoted provincially supervised nursing homes; otherwise the value was 0;

SCALE1: 1 denoted medium-sized nursing homes; otherwise the value was 0;

SCALE2: 1 denoted small-sized nursing homes; otherwise the value was 0.

Besides, the occupancy rate (OR),[27] provided beds (BEDS), square of BEDS (BEDS2), and Herfindahl index[28] (HERFIN) were included in the regression. The occupancy rate was used as a measure of resident flow and as a reverse measure of competition for patients. In order to attract more residents, a nursing home should improve its quality of care through more inputs. Therefore, the final impact on the efficiency scores could not be identified. BEDS and BEDS2 were used to measure the impact of size on the efficiency performance of nursing homes. Normally, a larger nursing home might take advantage of economy of scale and

[26] The variables of HOME1 and HOME2 are included to capture the different degrees of case-mix to the influence of nursing homes' performance. A lot of literatures discuss about the question of case-mix. Some papers (Nyman and Bricker, 1989; Nyman et al., 1990; Fizel and Nnnikhoven, 1992; Dusansky and Wilson, 1994, 1995; Kooreman, 1994; Bjorkgren et al., 2001; Fried et al., 1999; and Fried et al., 2002) classified the residents of nursing homes on a severity-of-illness and need-of-care basis in order to adjust the influences of case-mix on the measurement. Chattopadhyay and Heffley (1994) incorporated the ADL index and added case-mix constraints in the first-stage DEA estimations to control the influences of quality and case-mix. However, it was not so simple to control the effect of case-mix merely with one index. Most literatures added more than one environmental variable in the second-stage regression analysis to achieve a more accurate estimation (Nyman and Bricker, 1989; Nyman et al., 1990; Fizel and Nunnikhoven, 1992; Chattopadhyay and Heffley, 1994; Dusansky and Wilson, 1994; Kooreman, 1994). In our study, we include the case-mix variable in the second-stage regression.

[27] Nyman and Bricker (1989) defined the occupancy rate as (residents)/(beds); Kleinsorge and Karney (1992) defined it as (resident days)/(beds). Because the data about resident days of nursing homes were not available, the first definition was used in the estimation of our study.

[28] $HERFIN_k = \sum_{i \in k} (BEDSUM_i / \sum_{i \in k} BEDSUM_i)^2$, $k = k_1, ..., k_{19}$ represented the conditions of market competiton in the 19 subregions of Taiwanese Medical Networks. $BEDSUM_i$ denoted the total number of beds in the i^{th} subregion.

specialization; but at the same, it suffered the problems of coordination and management. The Herfindahl index was used to measure the impact of market competition on nursing homes.[29] Generally speaking, competition improved the efficiency performance, and expelled inefficiency out of the market. However, Fizel and Nunnikhoven (1992) were of the opinion that due to the existence of non-price competition, there was a negative relationship between market competition and the efficiency performance of nursing homes.

Table 4. Regression analysis of efficiency scores

Explained variable: efficiency score of MIX1Q			
	Estimated regression coefficient (t-value)		Estimated regression coefficient (t-value)
C	2.1692*** (3.0523)	C	2.7457*** (4.0889)
OWNER	0.1259 (0.8032)	HOME1	-0.2972** (-2.1529)
OR	0.6694*** (2.6950)	HOME2	0.0325 (0.2669)
LBEDS	-0.6627* (-1.8594)	OR	0.9755*** (3.6375)
LBEDS2	0.0594 (1.4530)	LBEDS	-0.9744*** (-3.1189)
HERFINDAHL	-0.0613 (-0.2709)	LBEDS2	0.0905*** (2.7176)
		HERFINDAHL	-0.0244 (-0.1261)
R^2 $\bar{R}^2$	0.2830 0.2067	R^2 $\bar{R}^2$	0.3404 0.2544
Explained variable: efficiency score of MIX2Q			
C	2.1529*** (3.0623)	C	2.7305*** (4.1747)
OWNER	0.1040 (0.6705)	HOME1	-0.3305** (-2.4578)
OR	0.6217** (2.5303)	HOME2	0.0253 (0.2132)
LBEDS	-0.6762* (-1.9178)	OR	0.9476*** (3.6278)
LBEDS2	0.0628 (1.5529)	LBEDS	-0.9797*** (-3.2194)
HERFINDAHL	0.0017 (0.0078)	LBEDS2	0.0920*** (2.8361)
		HERFINDAHL	0.0194 (0.1029)
R^2 $\bar{R}^2$	0.2481 0.1681	R^2 $\bar{R}^2$	0.3295 0.2420

[29] Several indexes about market concentration have been used in the literatures. For example, Nyman and Bricker (1989) used the dummy variables generated by locations and local wage rates as the measurement; Nyman et al. (1990) used the number of nursing homes as the index; Fizel and Nunnikhoven (1992) made use of the Herfindahl index; and Chattopadhyay and Heffley (1994) used the number of local nursing homes per capita.

Table 4. Regression analysis of efficiency scores (continued)

Explained variable: efficiency score of MIX1Q			
	Estimated regression coefficient (t-value)		Estimated regression coefficient (t-value)
C	2.2653*** (2.9461)	C	2.3731*** (3.0261)
LOC1	-0.0148 (-0.0988)	SCALE1	0.0910 (0.4221)
LOC2	-0.0506 (-0.4355)	SCALE2	0.1175 (0.3617)
OR	0.6902** (2.5326)	OR	0.6810** (2.2821)
LBEDS	-0.7449** (-2.0111)	LBEDS	-0.8718** (-2.2697)
LBEDS2	0.0722* (1.8157)	LBEDS2	0.0887** (2.0231)
HERFINDAHL	0.0279 (0.1345)	HERFINDAHL	0.0373 (0.1844)
R^2 $\bar{R}^2$	0.2761 0.1817	R^2 $\bar{R}^2$	0.2759 0.1815
Explained variable: efficiency score of MIX2Q			
C	2.3223*** (3.0697)	C	2.3296*** (3.0128)
LOC1	-0.0849 (-0.5759)	SCALE1	0.1142 (0.5375)
LOC2	-0.0593 (-0.5189)	SCALE2	0.1447 (0.4520)
OR	0.6816** (2.5419)	OR	0.6224** (2.1151)
LBEDS	-0.7871** (-2.1597)	LBEDS	-0.8805** (-2.3249)
LBEDS2	0.0782** (1.9984)	LBEDS2	0.0918** (2.1228)
HERFINDAHL	0.0501 (0.2456)	HERFINDAHL	0.0875 (0.4383)
R^2 $\bar{R}^2$	0.2491 0.1512	R^2 $\bar{R}^2$	0.2457 0.1473

Note 1: '*': 0.1 significance level; '**': 0.05 significance level; '***': 0.01 significance level.

2: Variables descriptions:

C: constant term;
OWNER: dummy variable for public-owned nursing homes;
HOME1: dummy variable for nursing homes that provided only medical care;
HOME2: dummy variable for nursing homes that provided both medical and life care;
LOC1: dummy variable for municipally supervised nursing homes;
LOC2: dummy variable for provincially supervised nursing homes;
SCALE1: dummy variable for medium-sized nursing homes;
SCALE2: dummy variable for small-sized nursing homes;
OR: occupancy rate;
LBEDS: the log of provided beds;
LBEDS2: log of squared BEDS;
HERFINDAHL: Herfindahl index;
$\bar{R}^2$: adjusted R^2.

The results of regression analysis in Table 4 suggested that the public ownership had a positive impact on the efficiency performance, but this effect was insignificant. Other dummy variables, which were also characteristics of nursing home, did not have significant influences on the efficiency performance, except at the nursing homes that provided only medical care. Occupancy rates did correlate with the efficiency scores, and the effect was significant. This result was consistent with those in the literature. The relationship between the size of nursing homes and the efficiency scores was significantly negative. The larger the size of nursing homes are, the less their efficiency performance are. However, this effect was diminishing (a significant positive coefficient of BEDS2). Thus, the coefficient of Herfindahl index was positive but insignificant.

VI. CONCLUSION

For years, scholars as well as the public has been questioning the resource utilization problem in the long-term care system. This study presented an empirical investigation into the efficiency performance of nursing homes in Taiwan. When we started the research, there were few preceding works. Common evaluation methods used by the government authorities were either simple ratios or scores given by professional reviewing groups. However, less systematic research has been done. This situation inspired us to conduct a more comprehensive and overall measurement.

In this study, we used the “Performance Evaluation Report of Nursing Homes in Taiwan Area” released by the Ministry of the Interior, 1995. The DMUs included the 53 institutions in Taiwan.

Although there were disputes concerning the definition of quality and its adequate measurements, our empirical results revealed that the inclusion of the quality of care into the estimation made a significant difference of the efficiency scores. Thus, we suggested that the quality of care should be suitably considered in measuring the efficiency scores.

U or K-W tests disclosed that the differences of efficiency scores between publicly owned and private nursing homes were insignificant. The differences between nursing homes with different kinds of services were insignificant when the quality of care was not included in the estimation models, but the differences became significant when the quality of care was included. The differences of efficiency scores between nursing homes of different governing authorities were insignificant no matter whether the quality of care was considered. Finally, the differences between nursing homes of different sizes were insignificant when the quality of care were not included in the estimation models, but the differences became significant when the quality of care was included.

The OLS regression confirmed the above results. Moreover, it was found that the occupancy rates had a significantly positive relationship with the efficiency scores. The relationship between the size of nursing homes and the efficiency scores was significantly negative, but this effect seemed to lessen. Finally, the influence of market competition measured by the Herfindahl index was insignificant.

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我國老人照護機構技術效率之研究 —資料包絡分析法的應用

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摘要

近年來台灣地區人口老化速度持續上升，老人照護問題值得重視。然而，長久以來，國內老人照護機構缺乏全面性、系統性的生產效率評估指標，致使公私部門資源於長期照護市場未能有效配置。為了避免廠商效率值發生 censoring 問題，本文利用修正的資料包絡分析法 (data envelopment analysis，簡稱 DEA) 模式，衡量台灣地區老人照護機構的生產效率狀況，藉以找出超效率 (super-efficient) 之照護機構。此外，進一步探討照護品質特性納入 DEA 模式與否，對照護機構生產效率的影響。最後，以非參數方法 Mann-Whitney U 檢定生產效率差異的顯著性，並利用迴歸模型解釋老人照護機構生產效率的可能原因。

關鍵詞彙：照護機構、技術效率、資料包絡分析法、長期照護

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