輔仁管理評論

中華民國 105 年 9 月，第二十三卷第三期，1-28

Apply the Data Envelopment Analysis to Evaluate the Operational Efficiency of Public Hospital: A Perspective on the Role of Nursing

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(收稿日期：105 年 03 月 28 日；第一次修正：105 年 07 月 12 日；
接受刊登日期：105 年 09 月 05 日)

ABSTRACT

This study analyzes the operational efficiency of public hospitals in Taiwan, with a special emphasis on the role of nurses. Nursing staff salaries are taken as a key input factor. We use the CCR model (Charnes, Cooper and Rhodes, 1978) of data envelopment analysis (DEA) to evaluate efficiency. The study includes 6 inputs and 3 outputs and covers all of 2010. 54 public hospitals are sampled and each is treated as a DMU. The empirical results show that more than half of the sample are relatively inefficient and need to take action to make improvements. An adjusted efficiency score is measured by excluding the inputs of full-time and agency nursing staff salaries; results show that the adjusted score is lower than original one. This finding suggests that nursing staff salaries make positive contribution to operational efficiency, though there may be room for improvement.

Keywords: Data Envelopment Analysis, Operational Efficiency, Public Hospital

I. INTRODUCTION

The public hospitals are typically not for profit that has to stay in line with domestic regulatory policy and must aim to raise the standard of healthcare and promote public health. The main priority is the efficient use of human and medical resources, particularly when government funding is limited; thus, the input-oriented model is the more appropriate model for analyzing such a system. Generally the most important resource, in which hospitals invest, apart from buildings and equipment, is the medical staff, a large proportion of which are nursing staff (around 40–60%). This is why, when hospitals try to control costs, they tend to focus on nursing staff. In the past, Taiwan has received the attention of

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advanced Western nations for its high level of economic development (as one of the "Four Asian Tigers") and for its high-technology companies (ACER, ASUS, TSMC, HTC etc.), but even more so for its universal healthcare (National Health Insurance). However, the pressure this universal coverage places on government finances is increasing daily and all manner of measures are being adopted to make savings. One such measure is the total budget system, which, because it reduces hospital funding, means that finding ways to actively keep down spending costs has become the number one issue of strategic healthcare management.

In April 2011, the Taiwan Healthcare Reform Foundation, a non-profit organization, issued a press release stating that the profitability of Taipei's publicly funded Veteran's General Hospital went from 4.1% in 2007 to 7.5% in 2009, but personnel costs fell from 42.3% to 39.6% of total operating costs during the same period. The obvious fact that staff salaries are slowly being compressed by public hospitals, not to mention private hospitals, raised a public outcry that Taiwanese hospitals were turning into "sweat hospitals". After an investigation, the Control Yuan, Taiwan's highest institution of oversight, issued a formal rebuke to the Executive Yuan, the Department of Health and the Council for Labor Affairs. The report pointed to three shortcomings. First, medical staffs are being overloaded in order to maximize service volume; on average, one nurse has to oversee the condition of 13.5 patients, which is already risky, and in one public hospital a single nurse was responsible for 63 patients, which nearly led to a calamity. Second, to lower costs hospitals prefer to use agency staff rather than full-time staff, which also gives rise to discontent over pay disparities for different categories of staff who do the same job. In order to keep down personnel costs, National Cheng Kung University Hospital employs over two hundred agency workers, but the turnover rate is high and eight out of ten members of staff are new. Agency workers also tend to be "squeezed" by hospitals for maximum output. Third, nursing staff are overworked: four or five hours of overtime per day are the norm, and of the 130,000 nurses in Taiwan, 100,000 are of child-bearing age, yet the majority will not marry or have children. Overwork and burn-out mean that some nurses can even become a danger to patients.

Personnel costs are not merely salaries but also comprise paid leave, pensions, labor insurance and other benefits; thus, they account for rather a high proportion of total costs, which makes personnel costs the prime target for cost control. Doctors' numbers are subject to healthcare regulation and they are also one of the hospital's sources of value, so it is not an easy matter to reduce their numbers. Thus, cost control efforts are directed more towards nursing staff: for example, by reducing full-time staff numbers and increasing agency staff numbers or even reducing nursing staff power altogether. On the one hand, this leads to a daily increase in the burden of care shouldered by clinical nurses; on the other hand, bringing in lower-paid agency workers to replace full-time staff leads to pay disparities between colleagues who perform the same jobs, which is not only detrimental to management but also influences nurses' personal investment in their job and may lead to a decrease in the quality of care.

Furthermore, operational efficiency in public hospitals is inevitably an important issue for countries coping with today's surging healthcare costs and deteriorating public finances. Hospital efficiency either means providing relatively high-quality output (care) with limited investment or saving resources but maintaining a certain standard of care. Data envelopment analysis (DEA), a common way of measuring efficiency, was first developed by Farrell (1957), building on work by Debreu (1951) and Koopmans (1951). DEA has a concisely defined measuring method and can deal with situations with multiple input types. On the basis of the efficiency measure conceived by Farrell (1957), Charnes, Cooper and Rhodes (1978) established a generalized mathematical method that uses linear programming to solve multiple-input and multiple-output problems, and it is this that was first called data envelopment analysis. The CCR model (named after Charnes, Cooper and Rhodes) can be divided into input-oriented and output-oriented versions: the former works with current levels of output and seeks to minimize input, while the latter works with current levels of input and seeks to maximize output.

This study will take a deep look at the operational efficiency of public hospitals focusing on the role of nursing personnel for three reasons. The operational efficiency of public hospitals has an impact on public health; it is important to enhance the quality of healthcare; and since the development of the national health insurance system, "sweat hospitals" have emerged in the healthcare market in Taiwan. This study places a particular emphasis on how nursing staff it into the healthcare system, to discuss in depth the effect of nursing staff salaries on hospital management. The research methodology is based on the multiple-input and multiple-output linear programming model of Charnes, Cooper and Rhodes (1978), who established the CCR model—a generalized mathematical model of data envelopment analysis which will be used to determine the hospital operational efficiency. A total of six input variables are used: number of open beds, number of doctors, number of nurses, number of other medical personnel, full-time nursing staff salary and agency nursing staff salary. Three output variables are used: number of days of hospitalization, number of surgeries, and outpatient and emergency visits. The study looks at data from the full calendar year 2010 and regards each hospital as a decision-making unit (DMU), for a total of 54 DMUs. These can be arranged into five public hospital types. Type A hospitals are managed by the Veterans Affairs Commission; Type B hospitals are run by the Department of Health; Type C are hospitals affiliated with national university medical schools and their branches, under the management of the Ministry of Education; Type D are military hospitals and public healthcare centers under the control of the Ministry of National Defense; and Type E are hospitals under the control of local government authorities.

This study will use efficiency analysis to answer the following three questions. First, are resources used efficiently in public hospitals? Second, do current levels of healthcare meet optimal targets? Third, does the suppression of nursing staff salaries have any significant effect on the efficiency of public hospital management? We use the CCR model to answer these questions by evaluating efficiency of 54 public hospitals in 2010. The empirical results show that more than half of the sample are relatively inefficient and need to take action to make improvements. It also supplies each hospital with a management reference, enabling them to reach their goals. An adjusted efficiency score is measured by excluding the inputs of full-time and agency nursing staff salaries; results show that the adjusted score is lower than original one. This finding suggests that the input of nursing staff salaries make positive contribution to operational efficiency, though there may be room for improvement. In a word, this study will help to raise general awareness about these matters and bring about rapid improvement of the professional nursing environment, while also providing material for future researchers working on related topics.

The remainder of this paper is organized as follows. Section II provides the background about the public healthcare system in Taiwan. Section III includes literature review. Section IV describes the research methodology. Empirical results and sensitivity tests are reported in Section V, and finally conclusions are presented in Section VI.

II. BACKGROUND

According to Department of Health statistics, in late 2010 Taiwan had 508 hospitals (82 public and 426 private), with 135,401 open beds (45,981 and 89,420, respectively) and 142,045 professional medical members of staff (43,577 and 98,468, respectively). In 2010, 25,340,238 person-days were spent in hospital (9,521,094 and 15,819,144, respectively). The ratio of public to private hospitals is around 1:2, with public healthcare services still making up quite a high proportion. The quality of healthcare has an enormous impact on public welfare, but, more importantly, operational efficiency is the key to whether it is possible to sustain healthcare provision.

In the early days of the public healthcare system in Taiwan, all hospitals were funded by the state, which provided 100% of the resources needed and paid all staff salaries through the civil service system. Now, under the current system, every hospital has its own operation fund and is an autonomous, financially independent unit, while the staffing system is also more complicated. Staffs hired under the old system are still treated as state employees, in accordance with law, but there are limits on numbers and payroll. Most employees are still within the public system, in conformity with rules for the appointment, pensions etc. of state functionaries. Although the government provides a yearly subsidy, the Legislative Yuan has decided that state subsidies will be decreased by 10% annually, which places a great financial burden on hospitals. Every hospital has a different type of budget, either because of its size or because of its place in a hierarchy. Some hospitals are affiliated subordinate units, such as National Taiwan University Hospital and National Cheng Kung University Hospital; others receive a budget from the Department of Health, e.g. Veterans General Hospital and Taipei Hospital;

still others are subsidiaries, such as the Tri-Service General Hospital Songshan Branch and the Chiayi Branch, Taichung Veterans General Hospital. Public hospitals in Taiwan are managed by five types of administrative bodies: (1) the Veterans Affairs Commission; (2) the Department of Health, which manages hospitals via management committee; (3) the Ministry of Education, including university-affiliated medical schools and hospitals; (4) the Ministry of National Defense (military hospitals managed by the Medical Affairs Bureau); (5) local government authorities. The above-mentioned categories are what the term “public hospitals” refers to in the present study.

Health insurance has been a very important factor in the running of hospitals because it is a source of income for healthcare provision. Before Taiwan set up the National Health Insurance system (hereafter, NHI) there were separate health insurance systems for private sector employees, state functionaries, farmers, the military etc., but these covered only 59% of the population. The vast majority of the more than 8 million who lacked health insurance safeguards were children under 14 or people over 65. In 1986, the government pledged to implement a national health insurance system. The Council for Economic Planning and Development and the Department of Health were responsible in turn for the two planning stages. On 1 March, 1995, the NHI system was finally officially launched and today it has a 99% coverage rate. In 1999, The Economist assessed Taiwan’s medical healthcare and declared it the world number two, second only to Sweden. On 11 November 2005, the New York Times published “Pride, Prejudice, Insurance” , an article by Paul Krugman, future Nobel laureate (2008, Economics) and Princeton professor, who praised the benefits of Taiwan’s universal healthcare, not only for providing the whole country with healthcare, but also for setting up a model from which the whole world could learn. On 19 February 2008, an editorial in the Annals of Internal Medicine, “Learning from Taiwan: Experience with Universal Health Insurance”, also recognized that Taiwan’s universal healthcare system had helped to improve the health of the vulnerable and thus lessened the incidence of sickness-induced poverty. The NHI system is one of our most important modern healthcare policies and has greatly helped to remove the barriers to medical treatment for the economically disadvantaged, thus destroying the vicious cycle of sickness and poverty. However, with the advent of NHI, the healthcare system has become the biggest buyer in the healthcare market, and the income each hospital earns through providing medical treatment and receiving healthcare resource allocations has a tremendous impact, for example, in terms of total budgets, ratings systems and the proportion of NHI beds allocated. This means that hospital healthc are provision is closely tied to the NHI system.

Nursing staff play an important role in medical treatment as they are responsible for the majority of care provision and they have the closest and longest contact with patients. But they also account for as much as 40–60% of hospital costs; thus, they have an enormous impact on hospital management and performance. In the fiercely competitive world of healthcare provision, nurses tend to bear the brunt of cuts when hospitals think about setting salaries and benefits (for example, by reducing staff numbers or substituting agency personnel for full-time staff) because they make up such a large proportion of the workforce. In March 2011, the National Audit Office conducted a special investigation into the conditions of clinical nursing staff across the country. The subsequent report pointed out that, over the last few years, healthcare providers have been forced to adapt to the impact of the NHI total budget system. In order to reduce running costs, hospitals have considered reducing full-time nursing staff numbers, increasing agency staff numbers and even reducing overall nursing staff power. Nurses' workloads are becoming progressively heavier, remuneration is rather low for agency staff, and there is a pay disparity between agency and full-time staff, which can lead to resentment about performing the same job for less pay and can impact nurses' professional aspirations. Thus, the present study specifically takes nursing staff power as a key element in hospital management and uses it to measure hospitals' operational efficiency while also analyzing the effect of nursing staff power on efficiency rates.

III. LITERATURE REVIEW

Data envelopment analysis (DEA) originated with the Pareto Optimality of Italian economist Vilfedo Pareto which states that, in some economic situations, it is impossible to improve the efficiency of any individual without also decreasing the efficiency of some other individual within the system. According to the concept of Pareto Optimality, when a system under measurement has reached the limit of efficiency: (1) there is no way to increase an output without also increasing an input or decreasing some other output; and (2) there is no way to decrease an input without also decreasing an output or increasing some other input. The earliest modern in-depth scholarly study on efficiency measurement was by Farrell (1957). On the basis of studies by Debreu (1951) and Koopmans (1951), he defined a simple method for measuring efficiency that could cope with several types of input. Farrell thought that a unit's efficiency comprised two components: technical efficiency (also called output efficiency and technical and scope efficiency), where maximum output is obtained from a given set of inputs; and allocative efficiency (also known as price efficiency), where the unit organizes its operations in such a way as to produce output at the lowest cost, while the input costs and output production methods are fixed. Combining these two ways of measuring efficiency yields the overall productive efficiency or overall efficiency.

In the DEA model, all assessed units select the input and output weights that maximize their efficiency score; that is to say, weight restrictions are identical and the inputs and outputs of each decision-making unit (DMU) are directed towards producing the highest level of efficiency. DEA uses a mathematical model to obtain a productive frontier that will serve as the basis for efficiency measurement; the production function does not require the mathematical forms to be specified. The model can be used to obtain information on each assessed unit's inputs and outputs and to compare the unit's actual measurements with its production frontier; in other words, the DMU's relative efficiency and inefficiency is measured in order to suggest how greater efficiency may be achieved. Envelopment is at the theoretical basis of the DEA approach to efficiency measurement. In economics terms, envelopment signifies the most beneficial input-output frontier, that which obtains the greatest output for a given input. The efficient units are joined with a straight line or a curve to make the efficiency frontier that envelops the efficient units. In geometrical terms, it is like using an envelope to sample the inputs and outputs of all units then finding the lowest boundary (i.e. the efficient frontier). Any DMU falling within the boundary has an efficient combination of inputs and outputs. If a DMU lies to the right of the boundary, this means that its combination of inputs and outputs is not efficient. The productive efficiency frontier contains information of the whole sample (including both efficient and inefficient samples), which is then sorted using a linear programming method.

Building on Farrell's (1957) concept of efficiency measurement, Charnes, Cooper and Rhodes (1978) established a generalized mathematical model which could deal with multiple-input and multiple-output linear programming. This was what came to be known as data envelopment analysis. They used Farrell and Fieldhouse's (1962) envelopment theory and Farrell's deterministic nonparametric approach to develop a relative efficiency measurement which could be used to evaluate multiple-input and multiple-output units. They looked at the hypothesis of constant returns to scale, i.e. that if any input were increased, there would be a corresponding rise in output. The input-oriented CCR model works with fixed levels of output and seeks to minimize input, while the output-oriented CCR model works with fixed levels of input and seeks to maximize output.

Past studies of operational efficiency tended to look at manufacturing; this was also extended to include service industries such as banking and accountancy. Berg, Forsundand Jansen (1991) used DEA to evaluate the operational efficiency of 107 Norwegian banks. Jerris and Pearson (1996) measured the productive efficiency of US accountancy firms in 1994 by looking at the per capita income of partners, accountants and other staff. In their analytical investigation of a large US accountancy firm, Knechel, Rouse and Schelleman (2009) analyzed the operational efficiency of individual auditing contracts by taking time worked as the input variable and eight types of auditing results as the output variables.

Since 1984, when Sherman first used DEA to analyze hospital efficiency, scholars from the US and European and Asian countries have been conducting research into the medical industry. From a 1982 sample of 22 public hospitals and 60 private non-profit California hospitals, Grosskopf et al. (1987) concluded that the public hospitals were more efficient. Cellini et al. (2000) analyzed the competitiveness and operational efficiency of hospitals in the Italian National Health System. These studies mostly took medical staff power and facilities as inputs, while taking the volume of service provided (e.g. visits to outpatient clinics and emergency rooms and hospitalizations) or the quality of medical care as indicators of output. However, another DEA study of the operational efficiency of 487 Florida nursing homes, Anderson et al. (2003) replaced the conventional staff power input with various costs, including treatment costs, premises costs and other related costs. They found that for-profit nursing homes were more efficient than non-profit ones, especially because non-profit homes hardly excelled at cost control.

In Taiwan, the hospital efficiency is an important issue after the NHI launched. Chang (1998) compared differences in efficiency among six public hospitals in Taiwan and found that the scope of services and proportion of retired veteran patients are negatively and significantly associated with efficiency, whereas occupancy is positively and significantly associated with efficiency. Chen and Huang (2005) adopted the DEA as an efficiency measurement technique to compare production efficiency across hospitals in Taiwan. Their findings indicated that private hospitals were operated more efficient than government-owned hospitals and most medical centers and regional hospitals appeared over-sized and inefficiencies of scale. Pan et al. (2006) used the DEA to investigate the performance efficiency of the 20 hospitals of Department of Health (DOH). Their results showed that there were different performance efficiency of the 20 hospitals of DOH, but there were no different performance efficiency before or after implementation of global budget. Lin et al. (2007) evaluated the operating efficiency of different types of public hospitals in Taiwan to find that Ministry of Education type is the highest overall efficiency and Ministry of Defense type was the largest dispersion of efficiency. Recently, Liu et al. (2013) employed the DEA for 20 decision making units (DMU) of one armed forces hospital to compare the operational efficiency before and after the import of Taiwan-Diagnosis Related Groups (Tw-DRGs) and found that the average efficiency score before the implementation of Tw-DRGs was higher.

The present study will employ the CCR model to analyze the operational efficiency of non-profit public hospitals in Taiwan. Apart from the inputs of medical staff power and numbers of open hospital beds (which is also an output indicator), we shall especially focus on the cost of the nursing staff payroll because of the important role that nurses play in hospitals and the suppression of their salaries. Thus, in addition to analyzing hospital efficiency, we shall also highlight the impact of nursing staff.

IV. METHOD

Given that public hospitals are not set up with the goal of multiplying service volume or stimulating demand for treatment, this study will take an input-oriented CCR approach. Taking as fixed each hospital's current outputs, we shall analyze their inputs (number of doctors and number of beds) to determine optimum input levels. If the CCR model returns a value of 1, the unit is efficient; if the value is less than 1, the unit is not efficient. The overall analysis conforms to standard DEA assessment methods and can be divided into the following four stages:

1. Basic data analysis: analyzing descriptive statistics for inputs and outputs of all units: e.g., largest value, smallest value, average efficiency value, standard deviation etc.
2. Efficiency analysis: using the CCR-derived relative efficiency value between 0 and 1; units with a score of 1 are deemed efficient, i.e. lying within the efficiency frontier; units with a score below 1 are deemed to be inefficient, and the degree of separation between the score and 1 indicates the distance from the efficiency frontier.
3. Slack variable analysis: analyzing relatively inefficient DMUs to find where their use of resources falls short and to determine the scope and direction of possible improvement.
4. Sensitivity analysis: creating efficiency scores with certain inputs or outputs suppressed and comparing them with the original efficiency scores. The greater the disparity, the greater the impact of the suppressed input or output on the public hospital's efficient functioning; conversely, the smaller the disparity, the smaller the impact.

The data for this study come from service volume information from 82 public hospitals in Taiwan gathered by the Department of Health in 2010 and the National Audit Office's 2011 special investigation into the conditions of clinical nursing staff in Taiwan, which asked hospitals to provide payroll information for full-time and agency nursing staff. However, envelopment analysis can only be applied to units with a high degree of homogeneity. Thus, of the 82 public hospitals which provided information, 28 are excluded because they are psychiatric hospitals, special sanatoriums or hospitals of Chinese medicine. The remaining 54 can be separated into five categories: 14 hospitals belonging to the Veterans Affairs Commission (Type A), 22 under the Department of Health (Type B), 5 under the Ministry of Education (Type C), 7 military hospitals and public healthcare centers under the control of the Ministry of National Defense (Type D) and 6 hospitals controlled by local governments (Type E). This study uses data from a full year (2010) and treats each hospital as a decision-making unit, for a total of 54 DMUs. The design for the CCR model of inputs and outputs is as follows.

1. Input variables

This study looks at the role of nursing staff in public hospital performance, with a special emphasis on average monthly salary information on full-time and agency nursing staff, to assess the variation in public hospitals' performance and see whether the rumoured "sweat hospitals" do in fact exist. This study uses a total of six input variables: number of open beds, number of doctors, number of nurses, number of other medical personnel, full-time nursing staff salary and agency nursing staff salary. These are defined below.

(a) Number of open beds: the sum total of all types of hospital beds available and authorized by local government for use, including both regular and special-use hospital beds. Regular beds are those installed by the hospital in specific wards or for general use by patients with acute, chronic or psychiatric illness, including beds for emergency patients, psychiatric patients, patients with chronic illness and patients with chronic psychiatric complaints. Special-use beds are non-regular beds installed by the hospital, including beds used for intensive care, psychiatric intensive care, burns unit intensive care, burns unit care, sub-acute respiratory care, chronic respiratory care, isolation, bone marrow transplant, palliative care, baby care (including beds and cribs), haemodialysis, peritoneal dialysis, recovery and emergency observation.

(b) Number of doctors: the total number of legally licensed attending and resident physicians (including Western medicine, Chinese medicine and dentistry) employed by and working in the hospital in 2010.

(c) Number of nurses: the number of legally registered nurses and licensed practical nurses employed by the hospital in 2010, including full-time and agency staff.

(d) Number of other medical personnel: medical staff who are not nurses or doctors employed by the hospital in 2010, including pharmacists and assistant pharmacists, medical technologists and technicians, medical radiological technologists and technicians, midwives, dental prosthetists and dietitians.

(e) Full-time nursing staff salaries: the average monthly salary of full-time nursing staff officially employed by the hospital for the duration of 2010; the figure includes the monthly salary and benefits.

(f) Agency nursing staff salaries: the average monthly salary of agency nursing staff temporarily contracted by the hospital for the duration of 2010; the figure includes the monthly salary and benefits.

2. Output variables

Three output variables are used: number of person-days of hospitalization, number of surgeries and number of outpatient and emergency visits. These are defined below.

(a) Number of person-days of hospitalization: the total number of person-days spent in hospital for the duration of 2010. This is not merely the number of people, but the cumulative sum of all stays of every person hospitalized (day of discharge not included).

(b) Number of surgeries: the total number of surgical operations undergone by outpatients and inpatients during 2010.

(c) Number of outpatient and emergency visits: the total number of patient visits (following registration and including diagnosis and treatment). Includes outpatient and emergency visits.

V. RESULTS

5.1 Descriptive statistical analysis

Once the input and output variables were established, a descriptive analysis of the original data was carried out in order to establish a foundation for the empirical analysis. The input and output variables for the 54 hospitals are shown in Table 5.1.

Table 5.1 Descriptive statistical analysis of input and output variables

Panel A: Full sample descriptive statistics

Inputs/Outputs	Largest value/score	Smallest value	Mean	Standard deviation
Open beds(beds)	3,807	22	678	706
Doctors (people)	1,186	10	154	261
Nursing staff (people)	2,778	9	430	603
Other medical staff (people)	739	9	123	161
Full-time nursing staff salary (NTD/month)	89,991	35,600	66,394	13,906
Agency nursing staff salary (NTD/month)	50,905	18,080	38,208	7,752
Hospitalizations (person-days)	880,606	395	154,185	180,986
Surgical operations (person-times)	85,982	6	8,254	14,536
Outpatient/Emergency visits (person-times)	3,304,238	25,508	505,200	650,830

Panel B: Comparison of means for the five hospital types

Type (DMUs)	Type A (14)	Type B (22)	Type C (5)	Type D (7)	Type E (6)
Open beds(beds)	817	424	1,084	740	878
Doctors (people)	189	61	420	171	175
Nursing staff (people)	512	234	886	439	563
Other medical staff (people)	139	69	236	138	165
Full-time nursing staff salary (NTD/month)	67,838	66,281	82,289	52,179	66,776
Agency nursing staff salary (NTD/month)	37,984	40,070	47,491	26,565	37,751
Hospitalizations (person-days)	207,669	86,756	282,096	154,359	169,836
Surgical operations (person-times)	11,330	3,783	17,641	9,302	8,427
Outpatient/Emergency visits (person-times)	511,686	304,875	973,945	563,780	765,623

Note: Five hospital types are as following: the Veterans Affairs Commission (Type A), the Department of Health (Type B), the Ministry of Education (Type C), the Ministry of National Defense (Type D) and local governments (Type E).

Panel A in Table 5.1 shows six inputs, as described below:

(a) Number of open beds: among the 54 public hospitals, the highest number of open beds is 3,807 (Hospital E01) and the lowest is 22 (Hospital B03), which shows a significant difference in hospital size. The mean number of open beds is 678 and the standard deviation is 706.

(b) Number of doctors: among the 54 public hospitals, the highest number of doctors is 1,186 (Hospital C10) and the lowest is 10 (Hospital B03). The hospital with the most open beds is not also the hospital with the most doctors. The mean number of doctors is 154, with a standard deviation of 261.

(c) Number of nursing staff: among the 54 public hospitals, the highest number of nurses is 2,778 (Hospital A10) and the lowest is 9 (Hospital B03). The mean is 430 and the standard deviation is 603.

(d) Other medical staff: among the 54 public hospitals, the highest number of other medical staff is 739 (Hospital A10) and the lowest is 9 (Hospital B03). Hospitals which employ the largest and smallest number of nursing staff also employ the largest and smallest number of other medical staff, respectively. The mean is 123 and the standard deviation is 161.

(e) Full-time nursing staff salary: among the 54 public hospitals, Hospital E04 pays the highest mean monthly salary (NT$89,991) to full-time nursing staff, and Hospital E05 the lowest (NT$35,600). The overall mean is NT$66,394 and the standard deviation is 13,906.

(f) Agency nursing staff salary: among the 54 public hospitals, Hospital E01 pays the highest mean monthly salary (NT$50,905) to agency nursing staff, and Hospital D02 the lowest (NT$18,080). The overall mean is NT$38,208 and the standard deviation is 7,752.

Three outputs are shown, as described below:

(a) Hospitalizations: among the 54 public hospitals, Hospital A10 counted the highest number of person-days spent in hospital (880,606 person-days) and Hospital B03 the lowest (395 person-days). The mean was 154,195 and the standard deviation was 180,986.

(b) Operations: among the 54 public hospitals, Hospital A10 had the highest number of operations (85,982 person-times) and Hospital A15 the lowest (6 person-times). The mean was 8,254 and the standard deviation was 14,536.

(c) Outpatient and emergency visits: among the 54 public hospitals, the hospital with the greatest number of visits to outpatient clinics or emergency departments was Hospital E01 (3,304,238 person-times) and that with the smallest number was Hospital B03 (25,508 person-times). The mean was 505,200 and the standard deviation was 650,830.

Further comparison of the 54 DMUs according to hospital type shows that there are 14 DMUs of Type A, 22 DMUs of Type B, 5 DMUs of Type C, 7 DMUs of Type D and 6 DMUs of Type E. Panel B of Table 5.1 shows each hospital type's mean scores for the six inputs: number of open beds, number of doctors, number of nursing staff, number of other medical staff, full-time nursing staff salary and agency nursing staff salary. Type C hospitals have the highest means for all inputs. They are run by the Ministry of Education and include two medical centers, which account for 40% of Type C hospitals. Medical centers are far larger than regional or district hospitals and therefore have larger inputs. Average salaries for full-time and agency nursing staff are lowest for Type D hospitals, which are military hospitals run by the Ministry of National Defense, and salaries for nursing staff in these hospitals tend to be lower. Number of nursing staff, number of doctors, number of other medical staff and number of open beds are smallest for Type B hospitals, which are run by the Department of Health; this may be because Type B hospitals tend to be more remote and receive smaller resources.

A comparison of the output means for each type of hospital shows that Type C hospitals (run by the Ministry of Education) have the highest mean for every output: hospitalizations, operations and outpatient/emergency visits. Type C hospitals include two medical centers, which account for 40% of the sample for this type. Because Type C hospitals are far larger than district and regional hospitals, they also have a comparatively large service volume. By contrast, the lowest means for all three outputs are found with Type B hospitals, which are run by the Department of Health. It may be that hospitals operated by the Department of Health are more likely to be located in remote areas, and thus their volume of service is comparatively small.

5.2 Efficiency score analysis

The present research uses an input-oriented CCR analytical approach, taking as fixed current levels of output for each hospital and using analysis to determine the most suitable levels of input. Where the CCR model obtains a score equal to 1, this comprises the relative efficiency reference set; scores less than 1 indicate relative inefficiency. The mean efficiency value for the 54 DMUs sampled by this study is 0.9156 and the standard deviation is 0.1165. 21 DMUs achieve an efficiency score equal to 1, and the lowest scoring hospital is B18, with 0.5199.

(a) **Reference group analysis**: the 21 relatively efficient DMUs can provide points of reference for the improvement of relatively inefficient units; these relatively efficient units are known as the reference set. Reference group analysis can tease out the shortcomings of each inefficient DMU from units lying within the efficiency frontier. The objective is to tell whether relatively efficient units are used as a point of reference and, if so, how frequently. The more frequently a DMU serves as a point of reference for another DMU, the greater its efficiency. Table 5.2 lays out the referencing of all inefficient DMUs and the 21 DMUs with an efficiency score of 1. As the table shows, 6 hospitals are referenced 10 times or more by relatively inefficient units: Hospital A13 is the most referenced (19 times) and has the highest efficiency strength, with Hospitals B08 and C11 coming in second place (18 times). The second group of efficiency strength includes Hospitals B01, A10 and A21, respectively. Considered in terms of hospital types, Type A (belonged to the Veterans Affairs Commission) has the most relatively efficient units, with 8 hospitals, including 3 whose reference count is 10 or higher. This shows both that more Type A hospitals are relatively efficient and that the strength of their efficiency is higher.

Table 5.2 Reference count for relatively efficient units

Type	A		B		C		D		E	
	DMU	RN*	DMU	RN	DMU	RN	DMU	RN	DMU	RN
	A13	19	B01	15	C11	18	D01	1	E01	7
	A10	14	B07	0	C20	9	D03	1	E05	5
	A21	10	B08	18			D06	2	E06	1
	A23	9	B10	0						
	A32	2	B11	2						
	A20	1								
	A30	1								
	A31	1								
DMU Total	14		22		5		7		6	
No. of DMUs where efficiency =1	8		5		2		3		3	
Efficiency [unit] ratio	57%		23%		40%		43%		50%	

Note: RN indicates the number of times a DMU has been referenced. Five hospital types are as following: the Veterans Affairs Commission (Type A), the Department of Health (Type B), the Ministry of Education (Type C), the Ministry of National Defense (Type D) and local governments (Type E).

(b) **Analysis of relatively inefficient units**: of the 54 DMUs surveyed in this study, 33 have an efficiency score below 1—these are the relatively inefficient units. As shown below, these units may be divided into four levels: between 0.9156 (the mean efficiency score) and 1, between 0.8 and 0.9156 (the mean efficiency score), between 0.7 and 0.8, and between 0.5199 and 0.6.

Table 5.3 Relatively inefficient units grouped into ranges

Efficiency score	**1–0.9156**	**0.9156–0.8**	**0.8–0.7**	**0.6-0.5199**
DMU	A15	A12	A11	B03
	A16	A14	A22	B18
	B02	B04	B12	
	B14	B05	B20	
	B15	B09	D07	
	B19	B13	E03	
	B22	B16	E04	
	C10	B17		
	C12	B21		
	C30	D04		
	D02	D05		
	E02			

As Table 5.3 shows, of the 33 hospitals which count as relatively inefficient units, those with the lowest efficiency scores, in the 0.5199–0.6 range, are B18 and B03. In the 0.7–0.8 range there are 7 hospitals: A11, A22, B12, B20, D07, E03 and

E04. In the range between 0.8 and 0.9156 (mean efficiency score) there are 11 hospitals: A12, A14, B04, B05, B09, B13, B16, B17, B21, D04 and D05. Considered in terms of hospital type, the two hospitals with the lowest efficiency scores are both in Type B (run by the Department of Health), whereas the three relatively inefficient Type C hospitals (belonged to the Ministry of Education) all have efficiency scores above the mean. Overall, the results of the efficiency score analysis show that Hospital A13 has the highest degree of efficiency, followed by Hospitals B08 and C11; among the relatively inefficient units, B18 has the lowest efficiency score and B03 has the next lowest, with all hospitals in the lowest range belonging to Type B.

(1) Slack variable analysis

Slack variable analysis assigns a score of zero to the differential variables of efficient DMUs; for relatively inefficient DMUs, the differential variables of inputs represent the degree to which inputs must be decreased, while the differential variables of outputs represent the degree to which outputs must be increased. By making these adjustments, the management goal (i.e. efficiency) will be reached. Using slack variable analysis to continue our analysis of inefficient DMUs enables us to pinpoint excessive inputs and deficient outputs. The results for the five broad hospital types are summarized in Table 5.4, below.

Table 5.4 Slack variable analysis of five hospital types

Type	Type A	Type B	Type C	Type D	Type E	Mean
Input						
Number of open beds	−14.2%	−22.0%	−1.3%	−19.5%	−23.5%	−18.5%
Number of doctors	−16.0%	−19.6%	−9.4%	−20.4%	−16.6%	−17.8%
Number of nursing staff	−18.9%	−19.6%	−15.0%	−14.5%	−18.1%	−18.3%
Number of other medical staff	−20.1%	−24.8%	−5.4%	−33.6%	−27.1%	−23.4%
Salaries of full-time nurses	−23.3%	−32.9%	−11.7%	−37.7%	−35.1%	−30.0%
Salaries of agency nurses	−25.1%	−26.9%	−4.1%	−14.5%	−19.6%	−22.3%
Output						
Hospitalizations	0.0%	4.6%	0.0%	1.4%	24.1%	4.7%
Operations	169.2%	14.7%	17.6%	15.5%	8.3%	42.6%
Visits to outpatients and emergency	3.9%	0.0%	0.0%	0.0%	0.0%	0.7%
Number of inefficient DMUs	6	17	3	4	3	

Note: Five hospital types are as following: the Veterans Affairs Commission (Type A), the Department of Health

(Type B), the Ministry of Education (Type C), the Ministry of National Defense (Type D) and local governments (Type E).

As can be seen from Table 5.4, overall the input with the most pronounced differential variable is “salaries of full-time nurses” (−30%). For hospital types B, D and E, this input is furthest from the efficiency target; for types A and C, it is the second furthest. This means that the relatively inefficient hospitals should reduce the salaries of full-time nursing staff in order to become more efficient. On the other hand, this means that hospitals which are already efficient have suppressed full-time nurses’ salaries in order to maintain their high operational efficiency. This also echoes the reports of higher authorities which indicate that hospitals are tending to replace full-time nurses with agency nurses in order to cut costs.

In the same way, the inputs with the second- and third-greatest differential variables are “number of other medical staff” (−23.4%) and “salaries of agency nurses” (−22.3%), which means these should also be reduced in order to make hospitals more efficient. However, as the comparison in Table 5.1 shows, mean salaries for full-time staff are higher than those for agency staff (NT$66,394>NT$38,208), whereas the mean differential variable for agency staff salaries is lower than that for full-time staff salaries.This makes a lot of sense: where input costs are high but ideal levels of output are not reached, this will naturally have a greater negative impact on relative efficiency.

Finally, the output with the lowest differential variable is “visits to outpatients and emergency”, with a mean of only 0.7%. This may be because; given the limits on their output capacity, public hospitals prioritize outpatient and emergency services. However, “operations” has the highest differential variable and is the main reason why these hospitals do not reach efficiency, particularly in the case of Type A hospitals (belonged to the Veterans Affairs Commission), which have a differential variable of as much as 169.2%. Taking a closer look at this type, it can be seen that in 2010 Hospital A15 had 12 doctors, 121 nurses and 28 other medical staff; it carried out 6 operations and received 36,746 visits to outpatient or emergency clinics, a daily average of a little over a hundred. Its differential variable for operations was as high as 999.9%, and for outpatient and emergency visits was 23.6%. This shows that, in order to reach levels of efficiency for outputs, Type A hospitals must adjust their operational strategy and adjust the volume of service in surgical operations and outpatient and emergency visits.

(2) Sensitivity analysis

Next, we put out of play two variables—full-time staff salaries and agency staff salaries—and compared the new efficiency scores with the old ones to see if there were any differences. In this way, we could see the effect of nursing staff salaries on the efficiency of public hospitals and determine whether or not so-called "sweat hospitals" really do exist. We compared the efficiency scores for the original 6 inputs and three outputs (called the original efficiency) and a new set of scores from which full-time staff salary and agency staff salary inputs has been excluded (called the adjusted efficiency). With these two inputs suppressed, the new overall mean for the 54 DMUs is 0.87128, lower than the original mean efficiency score of 0.91562, which shows that efficiency falls when salaries are wholly discounted. At the same time, the new standard deviation is 0.12180, higher than the original 0.11650, which shows a higher degree of spread. Out of the 54 DMUs, the new efficiency score was lower for 34 DMUs and remained unchanged for only 20. 11 DMUs had adjusted efficiency scores equal to 1, whereas 21 DMUs had original efficiency scores equal to 1, meaning that 10 DMUs have left the efficiency frontier. Meanwhile, the efficiency scores of the three lowest-rated DMUs were unchanged by the suppression of the two inputs.

Table 5.5 Differential comparison of original efficiency scores and adjusted efficiency scores (with two inputs suppressed)

Panel A: DMUs rated relatively efficient according to original scores

DMU	Original efficiency score	New efficiency score	Difference
E01	1	0.8124	0.1876
D01	1	0.8591	0.1409
A31	1	0.8652	0.1348
B07	1	0.8804	0.1196
D06	1	0.9078	0.0922
B01	1	0.9272	0.0728
A30	1	0.9345	0.0655
A20	1	0.9427	0.0573
D03	1	0.9528	0.0472
A32	1	0.9779	0.0221

Table 5.5 Differential comparison of original efficiency scores and adjusted efficiency scores (with two inputs suppressed) (Continue)

Panel B: DMUs rated relatively inefficient according to original scores

DMU	Original efficiency score	New efficiency score	Difference
D02	0.9846	0.7704	0.2142
E02	0.9888	0.7939	0.1949
C12	0.9948	0.8984	0.0963
E03	0.7200	0.6246	0.0954
A11	0.7226	0.6290	0.0935
B22	0.9529	0.8676	0.0853
B15	0.9457	0.8733	0.0724
B04	0.8069	0.7384	0.0685
B09	0.8883	0.8219	0.0665
D07	0.7356	0.6732	0.0623
B02	0.9297	0.8700	0.0596
B17	0.8001	0.7413	0.0588
A22	0.7936	0.7350	0.0587
C10	0.9675	0.9138	0.0537
D04	0.8974	0.8584	0.0390
B12	0.7598	0.7313	0.0286
E04	0.7939	0.7672	0.0267
B05	0.9146	0.8904	0.0243
D05	0.8015	0.7873	0.0142
B13	0.8769	0.8641	0.0128
C30	0.9988	0.9862	0.0125
A12	0.9072	0.8998	0.0075
B21	0.9086	0.9029	0.0057
B14	0.9845	0.9813	0.0032

As can be seen from Table 5.5, with two inputs suppressed 34 of the hospitals have new efficiency scores and they are all lower than the original efficiency scores, 31 DMUs have a new efficiency score that differs by 0.01 or more from their original score and Hospital D02 has the greatest disparity (0.2142), which means it is also subjected to the significant impact. 5 hospitals have a disparity of 0.1 or more: in descending order, E02 has a disparity of 0.1949; E01, 0.1876; D01, 0.1409; A31, 0.1348; and B07, 0.1196. 15 DMUs have a disparity of between 0.05 and 0.1 and 9 DMUs have a disparity of between 0.01 and 0.05. This shows that there are 30 public hospitals whose performance is clearly affected by the salaries of full-time and agency nursing staff.

In addition, we compare 11 DMUs still have efficiency scores equal to 1 with 10 DMUs have left the efficiency frontier for the two input variables, full-time staff salary and agency staff salary. The difference of means show that DMUs left the efficiency frontier have higher full-time staff salary and lower agency staff salary. The results imply that hospitals try to control the full-time staff salary and use more agency staffs to achieve the operation efficiency.

Overall, we can tell from the slack variable analysis and the sensitivity analysis that the salaries of full-time and agency nursing staff play an important role in the performance of public hospitals. Moreover, salaries have clearly been suppressed, which confirms that, in the context of this healthcare system, without appropriate labor protection regulations, nursing staff may be the victims of cutbacks.

VI. CONCLUSION AND DISCUSSION

The objective of this study was to analyze the operational efficiency of public hospitals in Taiwan and consider the point of view of nursing staff, in particular emphasizing nursing staff salaries. Using the CCR approach to data envelopment analysis devised by Charnes, Cooper and Rhodes (1976), this study uses 6 inputs and 3 outputs in total. The data covers 54 individual hospitals, or decision-making units (DMUs), for the entire year of 2010. The results show 33 hospitals with relative efficiency scores lower than 1, making 61.11% of the sample relatively inefficient units. This means that more than half of the public hospitals are in a position to be improved. When the inputs of full-time staff salaries and agency staff salaries are suppressed and the adjusted efficiency scores compared with the original ones, it can be seen that there is a substantial drop in efficiency. This shows that full-time staff salaries and agency staff salaries make a significant contribution to the performance of public hospitals and also suggests there may be room for improvement in nursing staff salaries.

1. The present study has discovered that some public hospitals in Taiwan have a rather low operational efficiency. There are a fair number of hospitals whose performance leaves something to be desired: two hospitals have an efficiency

score of less than 0.7 and 9 have an efficiency score of less than 0.8. The results of the efficiency scores, differential variables, and sensitivity analysis of this research enable each hospital to see whether it is using resources appropriately and whether its healthcare provision reaches its objectives. It also supplies each hospital with a management reference, enabling them to reach their goals. Moreover, hospitals can also reflect on whether to merge to bring inputs and outputs to levels of efficiency.

2. Nursing staff are the powerhouse of the healthcare system and account for 40–60% of the hospital workforce. The present study has found that the salaries of nursing staff play an important role in the efficient running of hospitals; thus, it is necessary to formulate appropriate labor law safeguards to make sure nurses do not become the victims of the intensely competitive environment of the National Health Insurance system.

Finally, in relation to the empirical evidence used by this study, certain limitations are unavoidable: (1) data envelopment analysis (DEA) is used to analyze the performance of Taiwan's public hospitals, but the analysis is affected by the selection of inputs and outputs—in other words, different inputs and outputs would yield different results. For example, the average monthly salary of is employed as one of input variables, but total nursing staff salaries maybe a meaningful variable for future studies. In addition, the working hour of nursing staffs is a good input variable for investigating this issue; (2) DEA is good at estimating relative efficiency of DMUs, but it has a gap to absolute efficiency. So the conclusions based on our data are finite external validity; (3) the samples included 54 hospitals are all public that lacks private medical systems to have a complete comparison for operational efficiency; (4) the difficulty of obtaining data means that this assessment is based on only one year of data and there is no way of forming a more complete picture of each hospital's performance on the basis of long-term data. Due to limitations of time and scope of research, the present study is not exhaustive. Future research could be longer-term, more different samples and deeper discussions, in order to discover long-term trends and rich policy implications to policymakers with more reliable information for the adjustment of operations. It may also bring in the issue of the quality of healthcare from the user's point of view, making research more relevant to the public and supplying the appropriate authorities with the proper policy decisions.

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運用資料包絡分析法探討公立醫院之經營效率：強調護理人員之角色

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摘要

本文研究之目的在於分析公立醫院的經營效率，並考量護理人員之觀點，特別將護理人力之薪資作為重要的投入項目。採用 Charnes, Cooper and Rhodes（1978）的資料包絡分析法（Data Envelopment Analysis, DEA），即所謂 CCR 模式來估算效率值，本文共使用 6 個投入變項及 3 個產出變項。研究期間為 2010 年一個完整年度，資料則以個別醫院為一決策單位（DMU），共包含 54 家醫院。實證結果發現，相對效率小於 1，即相對無效率者有 33 家，佔 61.11%。可見公立醫院中，半數以上仍處於效率待提升的狀態。而比較刪除正職護理人員薪資及約用護理人員薪資 2 項投入項測試其效率值與原效率值間的差異，發現平均效率值大幅下降。顯示正職護理人員薪資及約用護理人員薪資對於公立醫院經營績效有顯著的貢獻，也可間接觀察出護理人員待遇有改善之空間。

關鍵字：資料包絡分析法，經營效率，公立醫院

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