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Nursing manpower and productivity in medical service industry

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ABSTRACT

The Malmquist Index (MI) is a bilateral index that can be used to compare the production technology of two economies also as two different time status of one economy. Since, the nurse-to-bed ratio is the standard quantitative indicators of changes in technical efficiency, changes in technology, and total factor productivity in the medical service industry; we explore the link between the nurse-to-bed ratio and three MIs at the industry level using Twainese context. Our results show that the annual average nurse-to-bed ratio is inversely related to changes in efficiency in large cities. However, in medium-sized cities, annual changes in the average nurse-to-bed ratio are inversely related to the total factor productivity. We propose four assessment models to assist in the formulation of strategies aimed at improving the quality of care as well as productivity while considering the particulars of individual cities and regions.

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1. Introduction

Lack of sufficient medical manpower is a major global policy issue despite decades of attempts to control the problem(Barros, De Menezes, Peypoch, Solonandrasana, & Vieira, 2008; Conrad, 2009). Increasing healthcare capacity requires the adoption of advanced medical techniques and the efficient use of existing manpower. However, expansion can lead to considerable increases in healthcare revenue as well as costs. Nursing accounts for most personnel-related costs. A low nurse-to-bed ratio can increase efficiency(Farsi & Filippini, 2005; Herr, 2008); however, a high nurse-to-bed ratio can improve the quality of care(Association, 1997, 2000; Mark, Harless, McCue, & Xu, 2004). Researchers have yet to fully elucidate how these factors interact to improve medical outcomes as well as profits, thereby allowing sufficient growth to ensure the quality of healthcare services. The fact that expenditures increase over time has prompted hospital managers to establish hospital reimbursement systems to enhance efficiency, adopt new technologies (Burke & Menachemi, 2004; Nadzam & Macklis, 2001), and elevate total factor productivity(Glickman & Peterson, 2009; Tompkins, Higgins, & Ritter, 2009). Unfortunately, efforts to control healthcare costs often result in compromised healthcare quality.

Numerous researchers have investigated the relationship between medical personnel and the efficiency of hospitals in the provision of healthcare. The environmental and cultural conditions make a different change (Harrison, Henriksen, & Hughes, 2007; Singer et al., 2009). Researchers have applied efficiency estimation techniques such as data envelopment analysis (DEA) to measure efficiency at the hospital level(Sikka, Luke, & Ozcan, 2009). However, at the industry level, most research has focused on productivity.

The purpose of this research was to examine the 10-year period following the National Health Insurance employing for the 2nd decades. The study involves four stages of work. First, we used the National Health Insurance database to calculate the nurse-to-bed ratio in 22 counties and cities in Taiwan, i.e., at the industry level rather than at the hospital level. The index nurse-to-bed ratio at the industrial level indicates the scale of the medical service provider, remoteness of the facility, the investment by the government, different environment, and cultures. Second, we measured the three Malmquist indices (MIs): technical efficiency change (EFFCH), technological change (TC), and total factor productivity (TFP)(Färe, Grosskopf, Norris, & Zhang, 1994; Nishimizu & Page, 1982). Third, we conducted statistical analysis of Taiwan's medical service industry between2005 and 2014 (10 years) to identify correlations between the change in annual average nurse-to-bed ratio and efficiency, technological process change, and total productivity. Finally, based on the nurse-to-bed ratio and TFP, we divided the medical service industry in those 22 counties and cities into four groups. The study reveals the dynamic interactions of these indices and their implications.

2. Data and methodology

We employed a retrospective longitudinal-sectional observational research design. We divided the total number of nurses by the total number of beds in every county and city in Taiwan to obtain the nurse-to-bed ratio for each year. Analysis of the three MIs (EFFCH, TC, TFP) was conducted using four inputs and two outputs selected as per the DEA/Malmquist index method, which is a non-parametric frontier estimation approach.

2.1 Collected data

Data was obtained from the National Health Insurance database for the period 2005-2014. As recommended by Ozcan (2008), we selected four inputs: the number of doctors, the number of nurses, the number of other medical staff, and the number of beds. We selected two outputs: outpatient visits and several admissions. Ccharacteristics of the 22 counties and cities surveyed are listed in Table 1.

Table 1: Features of collected data

Scale	Numbers of beds	Nos.	Counties and cities
Large	More than 10,000 beds,	6	Taipei City (DMU: L01), Kaohsiung City (L02), Taichung City (L03), New Taipei City (L04), Taoyuan City (L05), Tainan City (L06)
Medium	More than 1000 beds, less than 10,000 beds	13	Changhua County (M01), Pingtung County (M02), Hualien County (M03), Yilan County (M04), Chiayi City (M05), Yunlin County (M06), Miaoli County (M07), Chiayi County (M08), Nantou County (M09), Keelung City (M10), Hsinchu City (M11), Hsinchu County (M12), Taitung County (M13)
Small	Less than 1000 beds	3	Penghu County (S01), Kinmen County (S02), Lianjiang County (S03)
Total		22	

Table 2 lists the variables addressed in the empirical analysis. The nurse-to-bed ratio is the measure of the loading of nurse manpower. The variable "NTB-A" refers to the average nurse-to-bed ratio each year in that city over a period of 10 years. The variable "NTB-AC" refers to the average change in the nurse-to-bed ratio each year. DEA/Malmquist index analysis was conducted using MaxDEA, and statistical analysis was performed using SPSS. According to the definitions of variables listed in table 2, we got summary statistics of the variable as listed in table 3 and table 4.

Table 2: Definitions of variables

	Variable name	Unit	Variable description
Input variables	Number of doctors	Persons	Number of full-time doctors
	Number of Nurses	Persons	Number of full-time nurses
	Number of other medical staffs	Persons	Number of full-time medical staff other than doctors and nurses
	Number of beds	Numbers	Number of beds
Output variables	Outpatient visits	Numbers	Number of outpatient visits and emergency visits
	Admissions	Numbers	Number of times admitted
variable	NTB-A	Ratio	Annual average nurse-to-bed ratio
variable	NTB-AC	Ratio	Average annual change in nurse-to-bed ratio from one year to the next

Table 3: Summary statistics of the variables

Variable name	Unit	Average	STD	Range
Number of doctors	Persons	2515	3087	15~12813
Number of Nurses	Persons	4922	5454	18~21831
Number of other medical staffs	Persons	1669	1898	10~7885
Number of beds	Numbers	7076	6990	36~24899
Outpatient visits	Numbers	15498365	15379498	123153~59598623
Admissions	Numbers	137799	122821	1086~460626
NTB-A	Ratio			
NTB-AC	Ratio			

Table 4: The nurse-to-bed ratio in each cities/counties between 2005 and 2014

NTB	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	NTB-A	NTB-AC
L01	0.815	0.831	0.829	0.838	0.854	0.851	0.855	0.861	0.888	0.877	0.850	1.008
L02	0.638	0.631	0.654	0.685	0.702	0.736	0.767	0.794	0.816	0.824	0.725	1.029
L03	0.638	0.633	0.652	0.669	0.672	0.694	0.702	0.726	0.746	0.734	0.687	1.016
L04	0.624	0.668	0.667	0.679	0.693	0.704	0.703	0.715	0.749	0.719	0.692	1.016
L05	0.572	0.590	0.628	0.654	0.671	0.672	0.688	0.714	0.723	0.732	0.664	1.028
L06	0.611	0.622	0.639	0.652	0.669	0.703	0.740	0.817	0.853	0.845	0.715	1.037
M01	0.687	0.653	0.702	0.667	0.691	0.697	0.708	0.738	0.752	0.769	0.706	1.013
M02	0.574	0.588	0.614	0.625	0.649	0.642	0.661	0.642	0.666	0.696	0.636	1.022
M03	0.482	0.494	0.499	0.497	0.514	0.507	0.499	0.508	0.507	0.519	0.502	1.009
M04	0.507	0.508	0.523	0.551	0.574	0.574	0.577	0.604	0.623	0.687	0.573	1.035
M05	0.583	0.581	0.592	0.665	0.670	0.661	0.661	0.700	0.714	0.748	0.657	1.029
M06	0.568	0.583	0.605	0.621	0.619	0.619	0.646	0.645	0.672	0.700	0.628	1.024
M07	0.465	0.495	0.490	0.461	0.472	0.469	0.488	0.509	0.552	0.547	0.495	1.019
M08	0.602	0.613	0.620	0.630	0.660	0.686	0.689	0.680	0.697	0.726	0.660	1.021
M09	0.509	0.504	0.511	0.524	0.542	0.536	0.555	0.557	0.572	0.559	0.537	1.011
M10	0.544	0.553	0.552	0.567	0.583	0.594	0.583	0.580	0.584	0.598	0.574	1.011
M11	0.698	0.719	0.718	0.804	0.851	0.869	0.869	0.898	0.924	0.910	0.826	1.031
M12	0.540	0.526	0.539	0.536	0.526	0.512	0.549	0.523	0.549	0.551	0.535	1.003
M13	0.627	0.661	0.651	0.643	0.638	0.655	0.649	0.668	0.709	0.706	0.661	1.014
S01	0.541	0.537	0.539	0.575	0.608	0.597	0.594	0.599	0.589	0.574	0.575	1.007
S02	0.324	0.348	0.441	0.493	0.650	0.639	0.658	0.654	0.637	0.417	0.526	1.046
S03	0.409	0.455	0.426	0.556	0.583	0.490	0.455	0.455	0.436	0.436	0.470	1.015

2.2 Malmquist index analysis

The Malmquist Index (MI) (Malmquist, 1953) can be used to assess changes in total factor productivity in a given period. The MI is obtained by multiplying EFFCHby TC. We multiplied the distance function of EFFCH and TC to acquire the distance function of the Malmquist index as follows:

$$\text{Malmquist index (MI)} = \frac{d_i^t(x_t, y_t)}{d_i^s(x_s, y_s)}\left[\frac{d_i^s(x_s, y_s)}{d_i^t(x_s, y_s)} \times \frac{d_i^s(x_t, y_t)}{d_i^t(x_t, y_t)}\right]^{1/2} \quad (1).$$

$$= \left[\frac{d_i^s(x_t, y_t)}{d_i^s(x_s, y_s)} \times \frac{d_i^t(x_t, y_t)}{d_i^t(x_s, y_s)}\right]^{1/2}$$

A change in technical efficiency is also referred to as catch-up effect. In other words, it is the extent to which the technical efficiency of a decision-making unit (DMU) improves or declines. Technological change (also known as innovation effect or frontier-shift effect) reflects changes in the frontier between the two periods. As shown in Eq. (1), the Malmquist index comprises four distance functions: dis (xs, ys), dit (xt, yt), dit (xs, ys), dis (xt, yt). Specifically, dis (xs, ys) and dit (xt, yt) measure the distance from an observation unit (DMU) to the efficiency frontier. When the Malmquist index > 1, it indicates an increase in TFP from S to T. When the Malmquist index = 1, it indicates that the TFP is constant. When the Malmquist index < 1, it indicates a decrease in TFP. Table 5 lists the correlations among the three MIs, NTB-A, and NTB-AC.

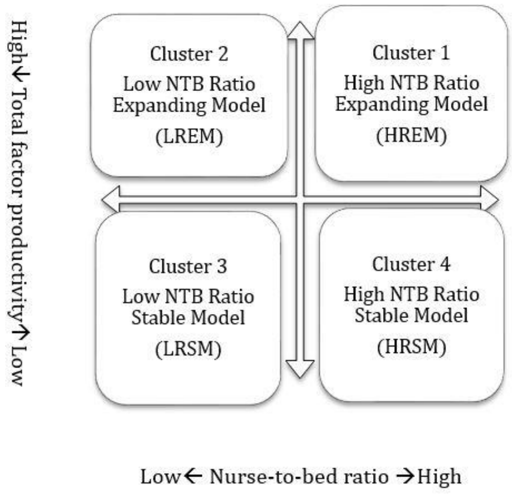
Table 5: Correlations among three MIs, NTB-A, and NTB-AC

	DMU	EFFCH	TC	MI	NTB-A	NTB-AC
Kaohsiung City	L02	0.979	0.994	0.974	0.850	1.008
Hualien County	M03	1.014	0.960	0.973	0.687	1.016
Keelung City	M10	1.009	0.962	0.971	0.715	1.037
Chiayi City	M05	0.993	0.991	0.985	0.725	1.029
Chiayi County	M08	1.001	0.980	0.981	0.574	1.011
Kinmen County	S02	1	1.027	1.027	0.826	1.031
Lianjiang County	S03	1	0.954	0.954	0.660	1.021
Miaoli County	M07	1.010	0.984	0.994	0.692	1.016
Nantou County	M09	1.012	0.978	0.990	0.664	1.028
Penghu County	S01	0.982	1.019	1.001	0.535	1.003
Pingtung County	M02	1	0.989	0.989	0.573	1.035
Taipei City	L01	1.018	0.987	1.005	0.496	1.019
Taitung County	M13	1.004	0.989	0.993	0.706	1.013
Tainan City	L06	1.003	0.982	0.985	0.537	1.011
Taichung City	L03	0.999	0.991	0.990	0.628	1.024
Taoyuan City	L05	1.020	0.977	0.997	0.657	1.029
New Taipei City	L04	1	0.979	0.979	0.636	1.022
Hsinchu City	M11	1.006	0.990	0.996	0.575	1.007
Hsinchu County	M12	1.023	0.981	1.003	0.502	1.009
Yilan County	M04	1.003	0.982	0.985	0.661	1.014
Yunlin County	M06	1	0.963	0.963	0.526	1.046
Changhua County	M01	1.006	0.983	0.989	0.470	1.015
Mean		1.004	0.984	0.987	0.632	1.020

2.3 Classification and models

As shown in Table 5, we classified the 22 counties and cities according to scale and calculated the correlations among the five variables to clarify the relationship between TFP and nurse-to-bed ratio. We then divided the 22 counties and cities into four quadrants based on the axes of the mean TFP and mean nurse-to-bed ratio. The analysis was conducted using the four assessment models in Figure 1.

Figure 1: Models used in analysis of TFP and NTB in various cities



3. Results

According to the data collection and statistical analysis, we got table 3. It revealed that the standard deviation and the distribution range are quite large among the variable of inputs and outputs comparing with the average. The types of metropolitan areas and remote areas cause this difference. This is also our interest. We would like to know how the lack of medical resources especially nurse manpower of medical resources impacts the medical productivity in different administrative regions. So, we standardize the data, which composes of nurse manpower to total bed ratio. Table 4 shows the NTB ratio, an average of the NTB ratio and average of annual changes in every cities/counties of various scale. We found that large-scale cities, their NTB ratio are all above 0.5 and most of them are at the forefront. While there is 2 cities' NTB ratio below 0.5, one is a medium-sized city, and the other one is a small city. Three scales of cities all can get the high average of annual change rate. That means to get the better medical resource and can lead to better medical output efficiency. It won't be the size of the city that inhibits the development of medical resource and so does medical output.

Table 5 summarizes the three MIs for the 22 counties and cities during the period 2005-2014. We calculated the annual average nurse-to-bed ratio and the average change in the nurse-to-bed ratio. The medical service industry averaged a 0.4% annual increase in EFFCH over the 10-year period. The TC component largely offset gains in the EFFCH factor, which yielded a decrease in TFP of 1.3% each year (mean = 0.987). The mean value of the average nurse-to-bed ratio in Taiwan was 0.632 during this period, and the mean value of annual changes in the average nurse-to-bed ratio was 1.020, which translates into 2% average increase in nursing manpower each year. Our objective was to elucidate how changes in the three MIs correlate to NTB-A and NTB-AC. The scale of the city/county was shown to influence the three MIsas shown in Tables 6.

Table 6: The correlations between three MIs and NTB-A, NTB-AC in three scales of the cities/counties

	Large beds capacity >10000		Medium beds capacity 1000-10,000		Small beds capacity < 1000	
Correlation	NTB-A	NTB-AC	NTB-A	NTB-AC	NTB-A	NTB-AC
EC	-0.745*	0.680	-0.153	-0.378	0.823	0.936
TC	0.414	-0.528	-0.059	-0.426	0.180	-0.063
TFP	-0.694	0.548	-0.149	-0.660**	0.426	0.194
Significance	NTB-A	NTB-AC	NTB-A	NTB-AC	NTB-A	NTB-AC
EC	0.045	0.069	0.309	0.101	0.193	0.115
TC	0.207	0.141	0.424	0.073	0.442	0.480
TFP	0.063	0.130	0.314	0.007	0.360	0.438

*: p<0.05, **: p<0.01

As shown in Table 6, EFFCH was inversely proportional to NTB-A (r=-0.745, p< 0.05) in the large cities. This is an indication that a high nurse-to-bed ratio is generally related to low technical efficiency, as described by Farsi and Filippini (2005). TFP was inversely proportional to NTB-AC in medium-sized cities (r=-0.66, p < 0.01).

Figure 2: Scatter plot of TFP and NTB ratio in the 22 cities/counties

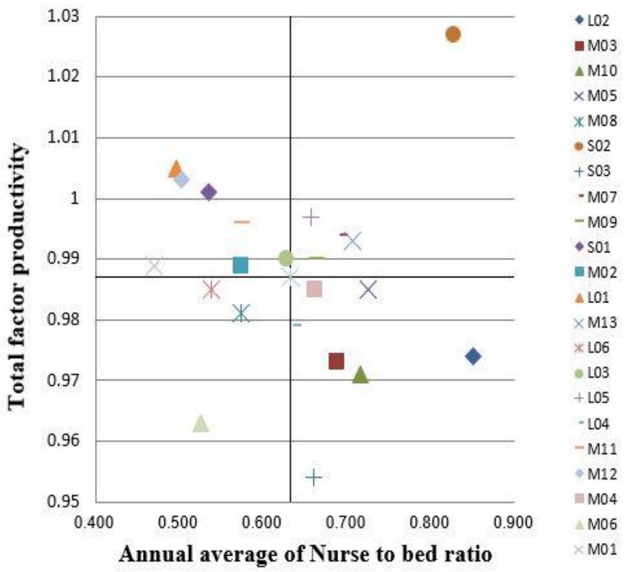


Figure 2 presents a scatter plot of TFP and NTB ratio in the 22 counties and cities examined in this study. The X and Y axes respectively present the mean values of NTB ratio and TFP with the 22 cities divided into four quadrants. As shown in Table 5, the TFP and NTB ratio are higher in the first quadrant, indicating that the quality of medical care in that city gradually increased. Medium-sized municipalities, such as Taoyuan City and Miaoli County, fall into this group. The city with the best care was Kinmen County, located in the outer island region with manpower support from the Veterans General Hospital in Taipei. The second quadrant lists cities with high TFP and low NTB. These facilities appear to be well-managed, showing constant growth and an adequate level of efficiency. The seven cities in the fourth quadrant provide high-quality medical care but present a decline in TFP. According to the table 5, grouping principle and description above, we get the scatter plot as Figure 2 and classify the 22 cities/counties into four groups as table 7.

Table 7: Classification of cities/counties according to performance

Groups	Types							Samples
First quadrant	HREM	S02	M07	M09	M13	L05		
Second quadrant	LREM	S01	M02	L01	L03	M11	M12	M01
Third quadrant	LRSM	M08	L06	M06				
Fourth quadrant	HRSM	L02	M03	M10	M05	S03	L04	M04

4. Conclusion and implications

Hospital managers and physicians seek to improve the quality of care as well as productivity; however, balancing the two objectives can be difficult, particularly within a National Health Insurance system. Increased nurse manpower can improve access to medical services for relatively underserved populations(Barer, Wood, & Schneider, 2014). Over the study period (2005-2014), hospital managers were shown to increase technical efficiency; however, they were unable to improve the underlying quality of care known as technological change. Overall, they decreased total factor productivity in Taiwan's medical service industry in the second decade of National Health Insurance. This means that TC accounted for a large proportion of the TFP. Increasing productivity first requires improvement of the underlying care processes. Technical efficiency can be improved by medical management measures such as decreased manpower and increased beds and examination equipment in short time. However, TC may be difficult to rationalize in terms of short-run return on investment and may be neglected. That is why we got lost of total factor productivity in the past decade. Increased qualified and registered nurse, improved underlying education process, elevated the motivation of willing to advocate to work and balancing the geographic distribution are the current workforce policies of our government. The conditions are the same as other medical staffs.

We also investigated the correlation between the three MIs and NTB ratio. In medium-sized cities, improvements in productivity were inversely related to increases in manpower. Improvements in productivity depended less on nursing manpower and more on efficiency where the number of beds is generally high. In this situation, nursing manpower can be controlled to improve efficiency.

As also we established four models for assessing the quality of care with a focus on productivity: high NTB ratio expanding model (HREM), low NTB ratio expanding model (LREM), low NTB ratio stable model (LRSM) and high NTB ratio stable model (HRSM). HREM refers to improvements in productivity based on high-quality care. Medium- to large-sized cities in more remote areas are included in this model. LREM refers to cases in which productivity was improved by controlling costs. Large urbanized cities, such as Taipei and Taichung, are included in this model. LRSM refers to cities that were unable to improve productivity despite controlling costs associated with nursing manpower. These areas require improvements in management skills. HRSM cities provide superior care without sacrificing productivity. These areas require improvements in efficiency strategies in order to become HREM. These models correspond to the current status of the medical service industry in Taiwan and can be extended to the same situation in National Health Insurance system and in the developing country. These four models cover the uneven development, and geographic distribution of the regions can provide the government policy makers the guidance in the development of strategies by which to improve productivity as well as the quality of care.

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