ORIGINAL ARTICLE

Evaluating the impact of COVID-19 on hospital efficiency: A stochastic distance function analysis of Japan's National Hospital Organization

Naomi Akiyama*[1], Noriyoshi Nakayama[2]

[1] *Graduate School of Nursing, Nagoya City University, Nagoya, Japan*
[2] *Graduate School of Economics, Nagoya City University, Nagoya, Japan*

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ABSTRACT

Background: This study seeks to provide insights into the factors that influence hospital performance during health crises to propose strategies for improving operational efficiency in future public health emergencies. It measures efficiency in national hospitals in Japan using a stochastic distance function approach on data from before and after the COVID-19 pandemic.
Methods: We collected data for financial years 2017, 2018, 2020, and 2021 (before and after the COVID-19 pandemic) related to the National Hospital Organization. The number of physicians, nurses, and others (including co-medical staff); the sum of costs; and the number of beds were used as input variables. The total numbers of inpatients and outpatients per year were used as output variables. The dataset comprised 140 national hospitals and spanned four years, resulting in 280 hospital observations pre- and post-COVID-19.
Results: The average number of inpatients at each hospital during the observation period was 109,141.5 (standard deviation [SD] = 37077.7), and the average number of outpatients was 84,324.5 (SD = 75050.4). The average numbers of physicians, nurses, others, beds, and costs were 46.9 (SD = 41.5), 62.6 (SD = 38.1), 278.7 (SD = 143.9), 363.5 (SD = 124.2), and 249,409,614.3 (SD = 2366015803.0), respectively. In the pre- and post-pandemic periods, the outpatient/inpatient coefficients were significant and positive, suggesting that the progression of COVID-19 led to a decrease in hospital efficiency.
Conclusions: While this study cannot definitively explain the efficiency decline, it provides important evidence indicating that the COVID-19 pandemic adversely affected hospital operations and revenue in Japan.

Key Words: Hospital efficiency, Stochastic Frontier Analysis (SFA), Output distance function, National Hospital Organization, Japan

1. INTRODUCTION

1.1 COVID-19 pandemic and hospitals

China reported a cluster of cases of pneumonia in December 2019. In 2020, the World Health Organization[1] declared the Coronavirus Disease 2019 (COVID-19) a pandemic based on the alarming levels of global infection cases. Human life has changed dramatically since the pandemic. Bankruptcies have increased in the hospital sector, linked directly to challenges emerging from the pandemic.[2] Hospital closures affect patients, healthcare providers, and policymakers as well as the

*Correspondence: Naomi Akiyama; Email: nakiyama888@gmail.com; Address: Graduate School of Nursing, Nagoya City University, Nagoya, Japan.

surrounding areas.[3] Hospital bankruptcy is also related to poor financial management and challenges related to payer mix and reimbursement. The revenues from outpatient services are associated with decreased financial distress,[4,5] and maintaining hospital functions in a crisis addresses the World Health Organization's Sustainable Development Goal 3, "Good health and well-being."

During the pandemic, hospital admissions in the United States (US) decreased,[6] as did healthcare service utilization in Japan, reflected in reduced hospitalization and outpatient visits.[7,8] These reductions led to a decrease in overall hospital output. Dupraz et al.[9] reviewed research published between 2020 and 2021 and found a 56% median relative cut in in-person outpatient care services. Today, as the effects of COVID-19 subside, research evaluating policies related to the pandemic is increasingly being published. Breitenbach et al.[10] reported that the average efficiency of global healthcare systems in managing COVID-19 deaths and infection prevalence rates was significantly low. Breitenbach et al.[11] and Lupu et al.[12] used data envelopment analysis (DEA) and found inefficiency in the healthcare system during the pandemic. Sülkü et al.[13] measured the efficiency of public hospitals under COVID-19 in Türkiye, where city hospitals had a negative effect on outpatient efficiency. Government response to COVID-19 included significant additional spending on hospitals and other health services. However, whether such a policy is appropriate to prepare for the next unknown infectious disease outbreak requires examination.

1.2 Hospital efficiency evaluation methods

Hussey et al.[14] conducted a systematic review of 172 articles on healthcare efficiency measures. The results showcased various methods and models, with two approaches being the most common in measuring hospital efficiency. Almost all the measures abstracted from the published literature used health services as output, DEA, and stochastic frontier analysis (SFA). DEA is the relative efficiency of a multi-input, multi-output enterprise that can be expressed as a scalar value from 0 to 1; however, considering external factors beyond the control of the enterprise is difficult. SFA can be actively incorporated, and target variables can be broken down into external influences, noise, and inefficiency; nevertheless, it is necessary to assume a production function.

Mahdiyan et al.'s meta-analysis[15] used both DEA and SFA, and found no significant difference in the mean efficiency score between the two methods. However, Watanabe et al.[16] noted that "some empirical studies using individual level data have also begun to employ parametric SFA rather than DEA." Studies conducted in Japan have employed SFA to measure hospital efficiency.[16–18] For instance, Kawaguchi et al.[17] estimated the efficiency of diagnostic procedure combination (DPC) data using SFA, and Besstremyannaya[18] investigated the efficiency of local public hospitals in Japan using SFA. Based on the literature review, SFA can be considered an effective method for analyzing hospital efficiency.

The objective of this study was to examine how hospital efficiency has changed between before and after the COVID-19 pandemic. Specifically, the study used SFA to analyze how the COVID-19-related patient inflow and government subsidies affected hospital efficiency. By identifying these effects, this research seeks to provide insights into the factors that influence hospital performance during health crises and to propose strategies for improving operational efficiency in future public health emergencies.

2. Method

2.1 Data source

The pre-COVID-19 pandemic period was represented by data from 2017–2018, and the post-COVID-19 pandemic period by data from 2020–2021. Four years of data were matched to the names of the 140 hospitals affiliated with the National Hospital Organization (NHO) and analyzed as cross-sectional data. The NHO was established in April 2004; before this, the national hospitals and sanatoriums were operated by the Ministry of Health, Labour and Welfare (MHLW) as independent administrative institutions. As the largest medical group in Japan, the NHO operates 141 hospitals as one organization. We excluded one hospital because it was consolidated or closed during the survey period.

Data, including those for outpatients, inpatients, and laborers, were obtained through a disclosure request to the NHO for research purposes. The labor count is presented as full-time equivalents, comprising physicians, nurses, and other staff. Data on the number of beds and quality indicators were obtained from the MHLW.[19] These data are part of the "Survey on impact evaluation of DPC introduction: tabulated results." Costs related to materials, pharmaceuticals, commissions, and other expenses were extracted from financial statements published on the NHO website.[20] To adjust for year-to-year price fluctuations, costs were divided by the gross domestic product deflator for each year obtained from the Annual Report on National Accounts by the Cabinet Office.[21]

2.2 Output distance function

SFA has been used to measure technical efficiency in previous studies.[16] Hospitals produce multiple outputs using multiple inputs. They are treated as a vector of inputs $x \in R_{+}^{K}$ to produce a vector of outputs $y \in R_{+}^{M}$.

The production technology of hospitals is defined as the output set:

$$P(x) = \left\{y \in R_+^M : \text{x can produce y}\right\} \quad (1)$$

The output distance function is defined on *P(x)* as:

$$D(x, y) = \min\left\{\theta : (y/\theta) \in P(x)\right\} \quad (2)$$

If *y* is located on the boundary of the output set, *D(x, y)* = 1. This result represents technical efficiency. If *D(x, y)* < 1, *y* lies inside the frontier, and technical inefficiency exists.

We adopt the output distance function specified in a translog form. The translog output distance function is defined below for N hospitals' inputs x_k (*k* = 1, 2, . . . , *K*) to produce outputs y_m (*m* = 1, 2, . . . , *M*):

$$\begin{aligned}&\ln D_{it}(x, y) = a_0 + \Sigma_{m=1}^{M}\alpha_m \ln y_{mit} + \frac{1}{2}\Sigma_{m=1}^{M}\\ &\Sigma_{n=1}^{M} a_{mn}\ln y_{mit}\ln y_{nit} + \Sigma_{k=1}^{K}\beta_k \ln x_{kit} + \frac{1}{2}\Sigma_{k=1}^{K}\\ &\Sigma_{l=1}^{K}\beta_{kl}\ln x_{kit}\ln x_{lit} + \Sigma_{k=1}^{K}\Sigma_{m=1}^{M}\delta_{km}\ln x_{kit}\ln y_{mit}\end{aligned} \quad (3)$$

The subscript *it* refers to the *i*th hospital in the *t*th period. The output distance function restrictions require the following conditions to hold:

a) Homogeneity of degree + 1 in outputs:

$$\begin{aligned}&\Sigma_{m=1}^{M}\alpha_m = 1,\\ &\Sigma_{n=1}^{M}\alpha_{mn} = 0, m = 1, 2, \ldots, M, \text{ and}\\ &\Sigma_{m=1}^{M}\delta_{km} = 0, k = 1, 2, \ldots, K\end{aligned} \quad (4)$$

b) Symmetry:

$$\begin{aligned}&\alpha_{mn} = \alpha_{nm}, m, n = 1, 2, \ldots, M \text{ and}\\ &\beta_{kl} = \beta_{lk}, k, l = 1, 2, \ldots, K\end{aligned} \quad (5)$$

By the homogeneity in output restriction, d(x, ωy) = ωD(x, y). Thus, the *M*th output can be chosen arbitrarily such that ω = 1/y$_M$. Thus, Equation (3) can be expressed as:

$$\begin{aligned}&-\ln y_{mit} = a_0 + \Sigma_{m=1}^{M-1}\alpha_m \ln(y_{mit}/y_{Mit}) +\\ &\frac{1}{2}\Sigma_{m=1}^{M-1}\Sigma_{n=1}^{M-1} a_{mn}\ln(y_{mit}/y_{Mit})\ln(y_{nit}/y_{Mit}) +\\ &\Sigma_{k=1}^{K}\beta_k \ln x_{kit} + \frac{1}{2}\Sigma_{k=1}^{K}\Sigma_{l=1}^{K}\beta_{kl}\ln x_{kit}\ln x_{lit} +\\ &\Sigma_{k=1}^{K}\Sigma_{m=1}^{M-1}\delta_{km}\ln x_{kit}\ln(y_{mit}/y_{Mit}) - \ln D_{it}\end{aligned} \quad (6)$$

Let u_{it} is -lnD_{it}, the output distance function to be estimated is:

$$\begin{aligned}&-\ln y_{2it} = \alpha_0 + \alpha_1 \ln(y_{1it}/y_{2it}) + \frac{1}{2}\alpha_{11}\\ &\ln(y_{1it}/y_{2it})^2 + \Sigma_{k=1}^{5}\beta_k \ln x_{kit} + \frac{1}{2}\Sigma_{k=1}^{5}\Sigma_{l=1}^{5}\\ &\beta_{kl}\ln x_{kit}\ln x_{kit} + \Sigma_{k=1}^{5}\delta_{k1}\ln x_{kit}\ln(y_{1it}/y_{2it})\\ &+ \upsilon_{it} + u_{it}\end{aligned} \quad (7)$$

where $\upsilon_{it} \sim N(0, \sigma_\upsilon), u_{it}^+ \sim N(\mu_{it}, \sigma_u)$.

The mean of u_{it}^+ is assumed to be a function of a set of explanatory variables:

$\mu_{it} = z_{it}\gamma$, and inefficiency term is $u_{it} = z_{it}\gamma + \omega_{it}$.

z_{it} is a vector of variables that explain inefficiency, and $\omega_{it} \sim N(0, \sigma_\omega)$.

2.3 Selecting variables

To assess hospital efficiency, we chose outputs and inputs in line with those used in previous studies.[22] Outputs comprised the annual total number of inpatients and outpatients. Inputs comprised the number of physicians, nurses, and other staff (such as pharmacists, medical radiology technicians, and clinical laboratory technicians), as well as the count of beds and total costs (encompassing material costs, expenses, and commission expenses). Total costs were a proxy for medical materials. The number of healthcare workers was calculated as the full-time equivalent in January each year. The bed count was based on figures from April 1 of each year.

To examine the relationship with efficiency, the study investigated a DPC dummy, the proportion of COVID-19 patients among inpatients (COVID-19 patient ratio), the ratio of subsidies for medical service revenue to total operating revenue, and the ratio of subsidies for others. The data were sourced from hospitals utilizing DPC as a reimbursement system for acute inpatient care in Japan.[23] The MHLW considers DPC hospitals superior, as they fulfill the numerous requirements of acute-care hospitals.

3. RESULTS

3.1 Data characteristics

Table 1 lists the data characteristics. Regarding output variables, the average annual number of inpatients was 84,324.5 before COVID-19 and 76,515.6 after. For output variables, the average annual number of inpatients was 109,141.5 before and 99,419.1 after. No significant difference was found in the number of outpatients between the pre- and post-COVID-19 periods (p = .199) or in the number of doctors, nurses, other staff, beds, or costs.

For subsidies, the medical service revenues for after (795,811,897.0) were far higher than those for before (20,597,209.0) (p < .001). The average number of COVID-19 patients was 1,275.1, accounting for 1.3% of the total number of patients.

Table 1. Characteristics before and after the COVID-19 pandemic

Items	Before	After	*p*-value	Test
	mean ± SD / *n* (%)	mean ± SD / *n* (%)		
Inpatient	109,141.5 ± 37,077.7	99,419.1 ± 33,135.3	.001	a
Outpatient	84,324.5 ± 75,050.4	76,515.6 ± 68,439.8	.199	a
Doctor	46.9 ± 41.5	47.3 ± 42.3	.925	a
Nurse	62.6 ± 38.1	66.1 ± 40.9	.295	a
Others	278.7 ± 143.9	280.4 ± 141.4	.888	a
Materials (yen)	2,494,096,143.7 ± 2,366,015,803.0	2,668,259,361.8 ± 2,540,172,353.1	.402	a
Bed	363.5 ± 124.2	356.7 ± 121.1	.516	a
Types of Hospitals				
DPC	154 (55.0)	152 (54.3)	.932	b
Non-DPC	126 (45.0)	128 (45.7)		
Number of COVID-19 Patients	-	1,275.1 ± 1,569.4	-	
Medical Service Revenue	20,597,209.0 ± 38,899,652.7	795,811,897.0 ± 835,352,526.6	< .001	a
Other Service Revenue	2,282,260.8 ± 5,221,803.3	3,020,541.6 ± 16,680,101.3	.480	a
Total Revenue	7,067,481,028.5 ± 5,206,797,566.5	7,921,291,406.7 ± 5,773,003,397.4	.067	a
COVID-19 Patient Ratio (%)	-	1.3 ± 1.6	-	
Medical Service Revenue Ratio (%)	0.2 ± 0.4	9.1 ± 8.8	< .001	a
Other Service Revenue Ratio (%)	0.0 ± 0.1	0.0 ± 0.1	.915	a

Note. a = using *t*-test; b = using χ^2 test; DPC = diagnostic procedure combination.

3.2 Parameter estimation before and after the COVID-19 pandemic

Table 2 presents parameter estimates using the stochastic distance function approach. Data from 140 hospitals were used, totaling 280 observations for each period. Inefficiency term u_{it} was assumed to follow truncated normal distribution. Output coefficients (outpatients/inpatients) showed significant and positive in all models, consistent with economic theory. The coefficients for nurses, others, materials, and beds exhibited significant and negative, whereas the coefficient for physicians was not statistically significant.

The Before_model and After_model1 examined the association between inefficiency, revenue, and DPC. In the Before_model, DPC, the medical service revenue and other services revenue ratios were not significantly associated with inefficiency. However, in the After_model1, the medical service revenue ratio was positively associated with inefficiency. When the variables for the medical service revenue ratio and the ratio of COVID-19 patients to total inpatients were included in the model, it did not converge. Therefore, in the After_model2, the ratio of COVID-19 patients to the total inpatients was positively associated with inefficiency.

Figure 1 illustrates the trend in inefficiency rates by hospital. The visualization highlights the variation in efficiency across institutions. The data used in this analysis consisted of 280 observations, comprising two years of data for each of the 140 hospitals, representing the before and after COVID-19 period. This bar graph was constructed using the inefficiency estimates obtained from Table 2 and arranged in order of each hospital. The visualization highlights the variation in efficiency across institutions.

3.3 COVID-19 pandemic effects on hospital efficiency

Table 3 summarizes the hospital's inefficiencies. In the Before_model, the mean efficiency was 0.051 (min–max; 0.009–0.369). In the After_model1 and After_model2, the mean efficiency was 0.093 (0.009–0.583) and 0.144 (0.009–0.471), respectively.

4. DISCUSSION

This study measured the inefficiency of national hospitals in Japan using SFA before and after the COVID-19 pandemic. The results lead us to draw three major conclusions.

4.1 Mean inefficiency at national hospitals

First, our findings show that the mean inefficiency of Japan's national hospitals was 0.057 before and 0.134–0.144 after the COVID-19 pandemic. The mean efficiency of these hospitals was 0.943 before and decreased after, ranging from 0.856 to 0.866. These values are considerably higher than those of overseas hospitals. Alatawi et al.[24] conducted a systematic

Table 2. Parameter estimation before and after the COVID-19 pandemic

	Before_model			After _model1			After_model2		
	Coef.	Std. Err.	*p* > z	Coef.	Std. Err.	*p* > z	Coef.	Std. Err.	*p* > z
Constant	-0.039	0.012	.001	-0.126	0.019	< .001	-0.136	0.019	< .001
Output									
(Outpatients/Inpatients)	0.123	0.016	< .001	0.136	0.019	< .001	0.149	0.020	< .001
Input									
Physicians	0.055	0.023	.017	0.030	0.030	.310	0.018	0.033	.598
Nurses	-0.136	0.031	< .001	-0.133	0.037	< .001	-0.150	0.040	< .001
Others	-0.183	0.043	< .001	-0.157	0.051	.002	-0.171	0.055	.002
Materials	-0.040	0.023	.076	-0.033	0.024	.167	-0.051	0.027	.058
Beds	-0.665	0.041	< .001	-0.686	0.050	< .001	-0.636	0.052	< .001
Quadratic Terms									
(Outpatients/Inpatients)× (Outpatients/Inpatients)	-0.005	0.027	.854	0.044	0.026	.085	0.075	0.028	.007
Physicians×Physicians	0.261	0.060	< .001	-0.064	0.096	.501	-0.166	0.116	.151
Nurses×Nurses	-0.146	0.126	.248	-0.294	0.126	.020	-0.178	0.129	.169
Others×Others	0.103	0.287	.719	0.025	0.394	.949	-0.147	0.432	.734
Materials×Materials	-0.176	0.094	.061	0.059	0.097	.543	0.005	0.109	.965
Beds×Beds	0.109	0.276	.693	-0.481	0.330	.145	-0.593	0.356	.096
Interaction Terms									
(Outpatients/Inpatients)× Physicians	-0.027	0.031	.384	-0.030	0.040	.451	0.001	0.046	.978
(Outpatients/Inpatients)× Nurses	0.188	0.058	.001	0.047	0.061	.434	-0.031	0.066	.642
(Outpatients/Inpatients)× Others	0.038	0.085	.657	-0.059	0.106	.580	-0.101	0.112	.368
(Outpatients/Inpatients)× Materials	-0.011	0.027	.690	0.011	0.038	.766	0.003	0.043	.943
(Outpatients/Inpatients)× Beds	-0.143	0.072	.047	0.039	0.074	.600	0.064	0.079	.416
Physicians×Beds	0.205	0.137	.135	-0.211	0.143	.138	-0.229	0.162	.158
Nurses×Beds	0.632	0.163	< .001	0.851	0.201	< .001	0.773	0.215	< .001
Others×Beds	-0.275	0.233	.237	0.133	0.292	.649	0.286	0.322	.375
Materials×Beds	-0.276	0.104	.008	-0.190	0.134	.158	-0.164	0.144	.256
Physicians×Nurses	-0.074	0.070	.295	0.293	0.088	.001	0.275	0.104	.008
Physicians×Others	-0.504	0.141	< .001	-0.023	0.183	.899	0.138	0.202	.495
Nurses×Others	-0.261	0.191	.171	-0.621	0.221	.005	-0.633	0.251	.012
Nurses×Materials	-0.117	0.108	.279	-0.201	0.092	.029	-0.140	0.100	.162
Others×Materials	0.654	0.133	< .001	0.354	0.141	.012	0.309	0.154	.044
Mu									
DPC	0.509	1.077	.636	0.079	0.019	< .001	0.079	0.021	< .001
Medical Service Revenue Ratio (%)	-44.915	97.993	.647	0.008	0.001	< .001	–		
Other Service Revenue Ratio (%)	-319.991	805.808	.691	-0.063	0.078	.419	–		
COVID-19 Patients/Inpatients	–			–			0.029	0.004	< .001
Constant	-1.049	2.638	.691	0.002	0.028	.950	0.056	0.025	.025
Sigma_u	0.246	0.272	.366	0.073	0.006	< .001	0.079	0.006	< .001
Sigma_v	0.037	0.005	< .001	0.026	0.007	< .001	0.023	0.007	.001
Lambda	6.590	0.271	< .001	2.830	0.011	< .001	3.433	0.010	< .001

Note. * The COVID−19 patients/inpatients, medical service revenue, and other service revenue ratios were included as variables that directly affect mean inefficiency. Coef. = Coefficient; Std. Err. = Standard Error; DPC = diagnostic procedure combination.

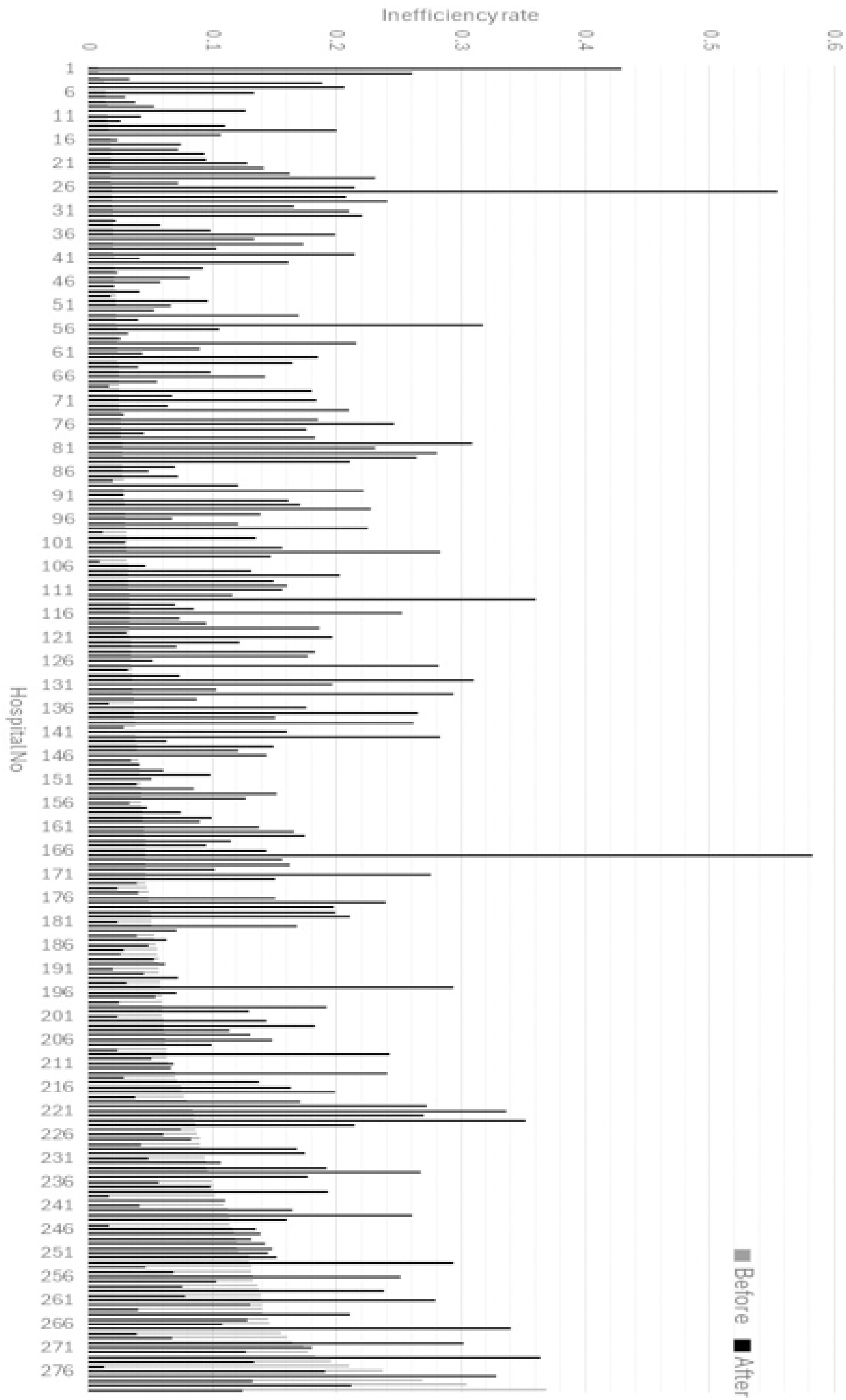

Figure 1. Trend in inefficiency by hospital

Table 3. Summary of the hospitals' inefficiency

	Before_model				After_model1				After_model2			
Variables	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Inefficiencies	0.057	0.051	0.009	0.369	0.134	0.093	0.009	0.583	0.144	0.088	0.009	0.471

Note. Coef. = Coefficient; Std. Err. = Standard Error.

review of hospital inefficiency in Gulf Cooperation Council countries and reported a technical efficiency rate of 0.792. Hamidi[25] used SFA and reported that the efficiency of government hospitals in Palestine was approximately 0.55. Li and Rosenman[26] reported on Washington State hospitals using a stochastic frontier panel data model and found the efficiency of the average hospital to be 0.67. Moreover, Choi et al.[27] reported the efficiency of US hospitals between 2001 and 2011, suggesting a mean efficiency of 0.428–0.514. This cost efficiency has decreased over the years.

Filippini and Farsi[28] reported an overall efficiency rate of 0.784 for Swiss hospitals; however, the efficiency rates differed among ownership/subsidy types. Yamamoto[29] explored hospital efficiency during 2015–2018 in public hospitals in northern Japan and found that efficiency rates had decreased over the study period to 0.824–0.856. Tanigawa[30] reported the results of the efficiency analysis for municipal hospitals using the translog cost function and DEA and found an average technical efficiency of 0.89–0.92. Compared to the results of these studies, our efficiency results were not significantly low.

National hospitals in Japan provide not only regular medical care but also care in accordance with national policies. These policies include inpatient treatment for patients with severe mental and physical disabilities, muscular dystrophy, and multidrug-resistant tuberculosis, as well as for patients who cannot receive treatment at private medical institutions. The proportion of patients admitted to national hospitals was much higher than that admitted to provincial hospitals.[31] Despite a large number of critically ill and time-consuming patients, hospital efficiency is relatively high. While this study focuses on technical efficiency using a stochastic frontier approach, hospital performance is inherently multifaceted and may be better captured by incorporating a wider range of indicators, such as waiting times, patient outcomes, and operational responsiveness. A more comprehensive evaluation of hospital efficiency — particularly during crises — calls for multidimensional approaches that combine both quantitative and qualitative indicators, including healthcare worker fatigue and psychological stress. Although this analysis is constrained by data availability, future research would benefit from adopting holistic frameworks, such as those proposed in the World Health Organization's 2000 report on health system performance.[32]

4.2 Changing mean efficiency due to COVID-19

The COVID-19 pandemic significantly impacted hospital management, leading to a marked decrease in inpatient and outpatient numbers. The decline in medical practice income caused a substantial drop in the profit margin of medical practices in Japan, from -1.3% in March-May 2019 to -12.0% in the corresponding period in 2020.[33] Our study reveals a gradual increase in inefficiency both before and after the COVID-19 outbreak. Sülkü et al.[13] observed consistent hospital efficiency scores for inpatient service from 2015–2019, with a notable change in 2020. The Japanese government offered subsidies to hospitals equipped to treat COVID-19 patients;[34] Nakayama's research[35] using local government hospital data showed a correlation between technical efficiency and subsidies, highlighting that higher subsidy proportions lead to greater inefficiency. Thus, COVID-19-related subsidies may have inadvertently increased hospital inefficiency measured by the medical service revenue ratio.

The results indicate that an increase in the number of COVID-19 patients led to greater inefficiency, as infectious disease patients require more time per person for care. From this perspective, COVID-19 revenue can be seen as appropriate support to address the increased inefficiency associated with patient care. However, the policy of providing substantial subsidies to hospitals that did not admit COVID-19 patients has also come under considerable criticism. As part of future infectious disease countermeasures, a review of the role and structure of hospital revenue, especially as a form of support for inefficiency caused by the admission (or lack thereof) of infectious disease patients, is necessary.

During the COVID-19 pandemic, hospitals were required to maintain empty beds to ensure they could admit patients at any time. To compensate for the financial burden caused by these empty beds, special subsidies were provided. However, in practice, large amounts of subsidies were also distributed to hospitals that had no record of admitting COVID-19 patients, which drew significant criticism. In the future, a policy to ensure the appropriate allocation of subsidies while safeguarding public health and safety will need to be formulated.

4.3 Limitations and future implications

This study has several limitations. First, it measures efficiency, without incorporating direct indicators of medical care quality. However, hospital efficiency is influenced by various factors, such as ownership, size/hospital capacity, market concentration, specialization, teaching status, membership in multihospital systems, case mix, and the outpatient–inpatient ratio.[36–38] Therefore, the inefficiency of the quality of care must be measured. Nevertheless, in Japan, data directly related to the quality of medical care—such as mortality rates or other outcome-based indicators—are not publicly disclosed, even by DPC hospitals. Furthermore, we were unable to incorporate operational indicators reflecting system stress during the pandemic, such as hospital closures, patient waiting times, ambulance diversion, or elective surgery delays. These valuable indicators of quality and system resilience are not publicly available or systematically collected in Japan at the national level and are essential for assessing system resilience and performance under crisis conditions. Their inclusion in future research would provide a more comprehensive evaluation of hospital functioning. We suggest that future research prioritize these indicators as they become more accessible. Improved access to data on healthcare quality is critical for enhancing both future research and policy development in Japan. The World Health Organization's 2000 report[33] proposed a broader framework for evaluating health system performance, encompassing not only efficiency but also overall health outcomes, responsiveness, and fairness in financial contribution. Future studies may benefit from applying such internationally recognized frameworks to provide a more holistic understanding of healthcare system performance. These insights offer valuable lessons for enhancing the resilience of healthcare systems. Therefore, future preparedness efforts should consider workforce stability, flexible resource allocation, and crisis governance.

Second, while this research utilized data from various hospitals, existing literature indicates that efficiency and economies of scale vary across sectors within the hospital system, such as between surgical and emergency departments.[39,40] Future studies should incorporate data on hospital characteristics as well. As healthcare costs escalate, understanding healthcare efficiency becomes increasingly crucial. We hope our findings can guide policymakers and hospital administrators in navigating the implications of unforeseen viral outbreaks on hospital management.

5. CONCLUSION

This study assessed the technical efficiency of Japan's national hospitals using SFA. The average technical efficiency of these hospitals was approximately 85.6%–86.6% after the COVID-19 pandemic. These efficiency scores are not low when compared with the results of previous studies, but are quite low when compared with the pre-COVID-19 pandemic level of 94.3%. Furthermore, the reduction in hospital efficiency due to the pandemic is indicated by the direct association between the proportion of COVID-19 patients and hospital inefficiency. The trend in the inefficiency rate was high throughout the pandemic. The results of this study suggest that government subsidies related to COVID-19 treatment could be associated with hospital inefficiency.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

DATA SHARING STATEMENT

No additional data are available.

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