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RESEARCH ARTICLE

# Technical Efficiency of North Eastern Region of India Health Systems in Combating COVID-19

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## Abstract

**Objectives:** To evaluate the relative technical efficiency of the health system of Northeastern states of India in their efforts to battle the COVID-19 pandemic. **Methods:** Data Envelopment Analysis (DEA) technique was employed. The outputs are the numbers of cured or discharged patients and people with second-dose vaccination. Public expenditure on medical and public health is the input. The constant return to scale (CRS) and variable returns to scale (VRS) are estimated with an output orientation. **Findings:** The results found that the mean technical efficiency score in the CRS model is 0.62 per cent and 0.72 per cent in VRS. In CRS model 25% of the states, namely Mizoram and Tripura with efficiency score of one are found to be most efficient whereas Mizoram, Assam, Sikkim and Tripura i.e., 50% are efficient under VRS model. In terms of scale efficiency, Mizoram and Tripura performed the best. For scale score, under decreasing return to scale (DRS), Assam with a score of 0.730 performed the worst and Sikkim is the only state that exhibits increasing returns to scale (IRS). **Novelty/Applications:** The use of the number of people vaccinated for the second time as an output is a novel feature of this study. It has been proved that vaccination plays a significant role in fighting disease. The findings demonstrate the relative effectiveness of states in combating COVID-19 utilising limited data. It helps in identifying the inefficient states and developing remedial measures for the least efficient states in time.

**Keywords:** COVID19; Efficiency; Data envelopment analysis; Vaccination; Northeast India

## 1 Introduction

The COVID-19 pandemic had devastating effects on the health systems and longevity of every country. However, the widespread and extraordinary COVID-19 vaccine rollout has significantly decreased the number of serious illnesses, hospitalizations, and fatalities, allowing societies to resume normal operations [(1)]. In addition., vaccination has avoided 14.4 million COVID-19 fatalities based on officially reported COVID-19 deaths [(2)]. Various authors attempted to study how efficiently available health resources are used in general [(3,4)] and in tackling the pandemic [(5–11)] using a non-parametric

method known as Data envelopment analysis (DEA). It is extensively applied in measuring the efficiency of health systems and is still among the most popular tools due to several advantages over parametric approaches such as stochastic frontier analysis (SFA)[12]. Some studies also assess the technical efficiency of Indian states in combating the pandemic adopting stochastic frontier analysis (SFA)[13] and also DEA[14]. These studies grouped together all the states, particularly in DEA model assuming that they are homogenous Decision-Making Units (DMUs) and calculated the efficient states that lies on the frontier. One of the drawbacks of this method is that, due to the vast variances in the availability of health resources among states, it will be a burden for the inefficient states to use resources like efficient states. According to the National Health Profile (2022), Northeast states have 10979 number of government allopathic doctors. Andhra Pradesh has the highest number of auxiliary nurses (ANM), at 139812, while Sikkim has the lowest, at 236[15].

The novelty of this study is in two ways: First, by using vaccination rate as an output because, to the best of the author's knowledge, no empirical research has used it, but also by considering the positive externalities associated with it. Second, by evaluating technical efficiency in a more homogeneous context for the North Eastern Region (NER) constituting Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim of India. In light of the given circumstances this study endeavors to address the current literature gap in the areas of assessing health system efficiency.

With this introduction and literature reviews the paper is structured into different sections. Section 2 methodology adopted, Section 3 constitutes the results and discussion, and in the last Section 4 the conclusion of the study is presented.

## 2 Methodology

A decision-making unit (DMU) is technically efficient if, with given inputs it can produce the optimum output. The efficiency score obtained is a scalar between 0 (the worst) and 1 (the best) relative to the sets of DMUs used to calculate efficiency. When calculating efficiency, the orientation of the DEA model can be an input, which keeps the output constant and intends to minimise the inputs. In contrast, an output-orientated DEA model aims at output maximisation without changing the inputs.

### 2.1 Model used to estimate efficiency in the study

Suppose that $k$ is the number of inputs and $m$ is the number of outputs and there are $n$ DMUs. Let $X$ be the input with $k \times n$ input matrix, and $Y$ be the output with $m \times n$ output matrix. For the $i$-th DMU, VRS DEA also known as Banker, Charnes and Cooper (BCC)[16] model with output orientation is specified by the mathematical programming problem given below:

$$Max_{\varnothing,\lambda}\ \varnothing, \tag{1}$$

Subject to:

$$-\varnothing y_i + Y\lambda \geq 0,$$

$$x_i - X\lambda \geq 0$$

$$N1'\lambda = 1$$

$$\lambda \geq 0$$

where $1 \leq \varnothing < \infty$ and the technical efficiency score is $1/\varnothing$ and it is between 0 and 1. If a particular DMU score is 1 it is said to be efficient, and if less than 1 it is considered to be an inefficient DMU. $\lambda$ is an $N \times 1$ vector of constants weights used to determine the position of an inefficient DMU if they were to become efficient. $N1'\lambda = 1$ is a convexity constraint and $N1$ is an $N \times 1$ vectors of ones. Using those weights, the DMUs which are inefficient would be projected as a linear combination of its peers on the frontier. The peer's DMUs are used as references as it consists of other DMUs which are more efficient. The Charnes, Cooper and Rhodes (CRR)[17] model under output orientation is also estimated in order to calculate the scale efficiency. If $N1'\lambda = 1$ constraint is removed from above equation (1), the model becomes a CRR model. The study will calculate an output oriented CRR and BCC DEA models so that scale efficiency of the DMUs can also be evaluated.

### *2.1.1 Scale efficiency*

The firm efficiency can also be enhanced by changing the scale of operations. Let the efficiency scores of CRR and BCC, assuming an output-oriented model be $\theta^*_{CCR}$ and $\theta^*_{BCC}$. Then the scale efficiency (SE) is

$$SE = \frac{\theta^*_{CCR}}{\theta^*_{BCC}}$$

where SE is a scalar not greater than one.

$\theta^*_{CCR}$ denotes the inefficiencies due to the input/output combination and operation size

whereas $\theta^*_{BCC}$ denotes pure technical efficiency score without scale efficiency.

Thus, the technical efficiency score is written as

Technical efficiency (TE) = Pure Technical Efficiency (PTE) X Scale efficiency (SE).

Since, it is not favorable to exceed the DMUs number to be more than double the number of inputs and outputs, the study adheres to only three variables.

### *2.1.2 Data and variables*

For efficiency analysis, the selection of input and output data is based on the literature and data availability. Although the inputs can be divided into monetary and non-monetary, this study adopted monetary measures as data for this is readily available. As input data, that is, the total expenditure of government health on medical and public health is used as an average of 2019-20, the actual and revised estimate of 2020-21, which was extracted from the Reserve Bank of India (RBI) annual publication - 'State finances: A study of Budget 2021-22'. Output variables are the number of persons cured/discharged, which denotes the overall effort of the government and health workers to combat the virus. The second output is the number of people who have successfully vaccinated with the second dose of COVID-19 vaccination, which reflects the state health policy measure to control the COVID-19 pandemic. Data of the output variables are collected from "Vaccination state data" and "COVID-19 State wise Status" up to 13$^{th}$ Dec 2021 published by the Ministry of Health and Family Welfare (MoHFW), Government of India (GOI). The software used to calculate efficiency is DEAP Version 2.1. 4.

**Table 1.** Abbreviation, definition and unit use in the model

| Variable | Definition | Unit |
|---|---|---|
| **Input variable** Health expenditure (HE) | Total expenditure of revenue and capital on medical and public health of the state | In Rs crore |
| **Output variables** Cured or discharged (CR) | These are people who were infected and have recovered | No. of people |
| Vaccinated with second dose(V2) | These are people who were successfully vaccinated with second dose | |

## 3 Results and Discussion

The input and output variables descriptive statistics are laid out in Table 2. Total health spending on medical and public health in the sample states ranges from a minimum of Rs. 549 crore in Sikkim with a maximum of Rs. 6697 crore in Assam. The mean expenditure is Rs. 1512 crore, with a standard deviation of Rs. 2100 crore. The number of persons cured/ discharged from Covid-19 ranges from 31354 in Nagaland to 609973 in Assam. The 2nd dose of Covid-19 vaccinated person has a minimum of 476481 in Sikkim to 13711672 in Assam. The average number of people in the states who have received the COVID-19 second dose vaccination is 2477056, with a standard deviation of 4568638.

**Table 2.** Inputs and output variables descriptive statistics among NER states

| Variable | Mean | Standard Deviation | Range | Min |
|---|---|---|---|---|
| Health expenditure (HE) in Rs. crore | 1512 | 2100 | 6148 | 549 |
| Cured or discharged (CR) | 144164 | 192041 | 578619 | 31354 |
| Vaccinated with second dose(V2) | 2477056 | 4568638 | 13235191 | 476481 |

Sources: Authors' calculation

Based on Table 3 the mean technical efficiency scores of CCR and BCC were 0.631 and 0.760. Assam, Mizoram, Sikkim, and Tripura are the four states that are efficient using the VRS DEA model, suggesting that 50% of the states responded to Covid-19

in an effective manner. Nagaland is the least efficient state out of the eight states; its scores were 0.322 in the CRS and 0.323 in the VRS DEA model, respectively. Two out of eight states are efficient when taking the CRS efficiency score into account. The only two efficient states under the CRS and VRS models are Mizoram and Tripura.

**Table 3.** Technical efficiency and scale efficiency scores of the NER states of India based on DEAP 2.1 efficiency result

| DMU name | Rank in CRSTE | CRSTE[a] | Rank in VRSTE | VRSTE | Scale[c] | Returns to scale |
|---|---|---|---|---|---|---|
| Mizoram | 1 | 1 | 1 | 1 | 1 | - |
| Tripura | 1 | 1 | 1 | 1 | 1 | - |
| Assam | 2 | 0.730 | 1 | 1 | 0.730 | Drs |
| Sikkim | 3 | 0.387 | 1 | 1 | 0.387 | Irs |
| Manipur | 4 | 0.776 | 2 | 0.836 | 0.928 | Drs |
| Meghalaya | 5 | 0.498 | 3 | 0.552 | 0.902 | Drs |
| Arunachal Pradesh | 6 | 0.335 | 4 | 0.372 | 0.900 | Drs |
| Nagaland | 7 | 0.322 | 5 | 0.323 | 0.996 | Drs |
| Average | | 0.631 | | 0.760 | 0.855 | - |

CRTSE denotes technical efficiency score from CRS DEA VRSTE denotes technical efficiency score from VRS DEA Scale denotes scale efficiency = CRSTE/VRSTE DEA Drs = Decreasing returns to scale Irs = Increasing returns to scale Sources: Authors' calculation

The average scale efficient score was 0.855, indicating that scale inefficient states need to improve the scale efficiency by 15%. Sikkim showed increasing returns to scale and four states (Arunachal Pradesh, Assam, Manipur, Meghalaya and Nagaland) showed decreasing returns to scale.

The earlier research evaluated efficiency using stale data. As states in NER face, acute shortage of reliable data and hence a larger number of inputs and outputs will not necessarily yield better results. The inefficiency score obtained by this study is in contrast to the findings of[13] if the Northeast states are considered. Their analysis included only four states namely, Arunachal Pradesh, Assam, Manipur and Meghalaya, out of which Manipur is the worst performer, i.e., it has the least efficiency score of 0.078 and Meghalaya with a score of 0.706 is the best performer. This differences in results may result from the authors' use of different methodologies, such as SFA. A study by[14] used another method, such as DEA, and Manipur also featured in the efficient states. However, when only the BCC model is used, the efficient states Mizoram, Sikkim, and Tripura are similar to the findings of this study. Also,[18] argued that Mizoram has done an exemplary work in controlling the pandemic using vaccination data, death ratio, and infection rate using technique such as scatter diagrams.

Table 4 highlights the peers or reference sets of the inefficient DMUs. It is evident that 4 times Assam and Mizoram appeared as a reference set for the 4 inefficient states and Tripura for three states. Overall, these three states can act as the reference set for the inefficient states.

**Table 4.** Summary of peers based on the DEAP 2.1 efficiency result

| DMU name | Peers | | | Peers count |
|---|---|---|---|---|
| Arunachal Pradesh | Assam | Tripura | Mizoram | 0 |
| Assam | Assam | | | 4 |
| Manipur | Assam | Mizoram | Tripura | 0 |
| Meghalaya | Assam | Tripura | Mizoram | 0 |
| Mizoram | Mizoram | | | 4 |
| Nagaland | Sikkim | Assam | Mizoram | 0 |
| Sikkim | Sikkim | | | 0 |
| Tripura | Tripura | | | 3 |

Sources: Authors' calculation

Putting off being vaccinated endangers the current COVID-19 pandemic and future pandemics[19]. The greater the number, the better the health system's effort in fighting the disease. It is pertinent to point out that the due to differences in inputs and outputs, the findings of the relative efficiency of the NER states health systems varies even when the same methodology are utilized. As a result, these outcomes are not strictly comparable.

## 4 Conclusion

This study assessed the efficiency of eight North-eastern states of India in combating the Covid-19 pandemic using an output-oriented DEA model with health expenditure as input and number of recovered cases, and number of persons with second dose vaccinated as outputs. The findings show that four states, i.e., 50%, are efficient out of the eight states in VRS assumption model and two states i.e., 25% in the CRS DEA model. Scale efficiencies indicate that most of these states are operating at decreasing returns to scale. With their resource constraints, these states are performing well in reducing and controlling the spread of the pandemic. Due to the limited sample size, the input and output are constrained to only three variables; another limitation is that the efficiency score purely depends on the input and output variables; any change in it will lead to a change in the score. Despite these limitations, this study shows relative efficiency in the public health initiatives in the states of NER in managing the COVID-19 pandemic. The health systems of Mizoram and Tripura are on frontier in both models, and the remaining states are not found to be efficient in both models. Therefore, it will be helpful for other states to closely examine the experience of Mizoram and Tripura, as these are more similarly situated. Further research can add other explanatory variables which affect the efficiency scores or can adopt different methods such as slack-based DEA models to assess efficiency.

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