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Performance Evaluation of Indian states healthcare systems in the management of COVID -19 recovery rate using DEA

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Abstract:

Purpose: This study aims to evaluate the efficiency of the Indian state's health care systems in increasing the recovery rate of the Corona virus by using data envelopment analysis.

Methodology: The Data envelopment analysis (Output Oriented CRS Model) has been applied to evaluate the efficiency scores of Indian states concerning the recovery rate of people affected by COVID -19. The tobit regression model is used to find the efficiency drivers. The required corona data has been collected during the period of time Feb 2019 - May 2020 from the government official websites like Worldometer, MoHFW, Corona Tracker etc,.

Findings: The efficient states were found along with the factor that increases the state's efficiency in increasing the recovery rate. The study reveals that out of 36 State/UT, only 5 State/UT were efficient in increasing the recovery rate. In addition the study found that there is an input slack in the number of hospitals for inefficient states/UTs.

Key words: DEA, Efficiency, Covid-19,Recovery Rate, Health care system.

1. Introduction:

Covid – 19 (Coronavirus - SARS- Covid 2) is an infectious disease that was found in Wuhan City, China in December 2019 and it is communicable from human to human through the surfaces, air, etc. For the last one-half years the countries are struggling to control the contagious of Covid - 19 and trying to increase the recovery rate by the implementation of lockdown, increasing the testing facility, strengthening the health care system, and vaccination.

In India, the first Covid -19 case was found in Kerala state in January 2020, the reason behind was the arrival of an individual from Wuhan city, China. At a snail's pace the virus spread all over India through people returning from foreign countries.

In the first wave, the virus affected the elderly people especially the people who were above 60 years of age and eventually the youngsters and children were unaffected at the initial period. But later the second wave hit the youngsters also and led to a higher death rate due to non-availability of Beds, lack of ventilators and insufficient oxygen mask in hospitals since the widespread of the mutant SARS COVID -19 viruses. In this pandemic situation, the health care

ISSN 2515-8260 Volume 09, Issue 8, 2022

systems of each country play a vital role in increasing the recovery rate and reducing the death rate due to corona virus. All the countries are in the position to strengthen the health care systems to save lives. This pandemic situation induces the researcher to know the efficiency of Indian health care systems in managing the COVID – 19 recovery rates as so far no study has been found in this topic in India.

1.1. Objective of the Study:

The objective of this study is to find the efficiency of 36 Indian State/UT s health care systems in increasing the recovery rate of corona patients by using the Data Envelopment Analysis (DEA).

2. Review of Literature:

Hadi Shirouyehzad (2020) [1] studied the efficiency of 29 countries' health care systems in contagion control and medical treatment effectiveness. In this study, the researchers found the efficiency of 29 countries based on controlling the spread of the novel corona virus and treatment using DEA methodology. In this paper, the countries have been classified into 4 groups according to their efficiency level in controlling the spread of the corona virus and effective treatment level. The researchers found that Singapore, Belgium and Vietnam performed well in both controlling the contagion and effective treatment level. Specifically in Southeast Asia, Singapore has performed well. In Europe, Belgium has performed very well as compared to other countries. In the Middle East, Iran performed efficiently in contagion control whereas Egypt performed well in treatment but least in contagion control.

Nahia Mourad et.al. (2021)[2] have made a study on the topic " Appraising health care systems efficiency in facing COVID - 19 through data envelopment analysis". In this study, the researchers found the efficiency score of 29 countries (over 20 million population) health care systems in facing the spread of covid-19 over the period of Jan 2020- Sep 2020. Based on the efficiency scores, the countries are categorized into four groups as completely efficient, nearly efficient (scored 90% or above), inefficient (Efficiency Score =between 70% and 90%) and severely inefficient (efficiency score=below 70%). Tobit regression and some other statistical tools have been performed to find the validity of the DEA results.

Muhammed Ordu et.al.(2021)[3] assessed the efficiency of 16 countries' health care systems using DEA approach . Five continuous weeks' covid 19 data after the 100th confirmed cases have been taken for this study. The researchers found the efficiency and super efficiency scores for 16 countries. The researchers have developed 80 DEA models for each week and found that the % of countries' efficiency scores decreased from 43.75% to 25% over the period of 5 weeks. The researchers concluded that China and South Korea increased their effectiveness in controlling the death rate and spread of the novel coronavirus.

Mustapha D Ibrahim et.al.[4] made a study on the topic "Pandemic response management framework" based on the efficiency of covid 19 contagion control and treatment. They have analyzed the efficiency of 58 countries based on controlling the contagion and treatment effectiveness. In this study, the researchers found that 89.6% of the countries are inefficient in controlling the spread of the novel coronavirus and 79% of the countries are inefficient in taking corrective treatment measures to increase the recovery rate of the corona patients.

ISSN 2515-8260 Volume 09, Issue 8, 2022

Dutta Arijita., et al (2014)[5] evaluated the efficiency of West Bengal government hospitals by applying the DEA model. The researchers found that out of 78, only 26 hospitals are relatively efficient with an average efficiency score of 0.73. The researchers found also that there is an input slack in the utilization of doctors and group D staff.

3. Research Design and Methodology:

3.1. Data:

The required coronavirus data have been collected from Worldometer, corona tracker, Kaggle, GitHub, etc over the period of time Feb 2019 - May 2020. The number of hospitals, Total number of COVID-19 testing till 17th May 2020, and COVID - 19 Confirmed cases of the 36 Indian State/UT's were considered as inputs in this research paper. The number of recovered cases from the COVID-19 virus over the period of time Feb 2019 - May 2020 is considered as an output for this research.

3.2. Methodology:

The Data Envelopment analysis (DEA) has been used to find and compare the efficiency of 36 Indian state health care systems in increasing the number of COVID -19 recovered cases.

3.2.1. Data Envelopment Analysis:

D.E.A is a non-parameter approach which is used to find the efficiency of decision-making units (DMU). In this research paper, the researcher uses the Output oriented CCR DEA model as the output (No. of recovered cases from COVID -19) has to be maximized by keeping the inputs at the same level which was developed by Charnes et.al.

The CCR- Output oriented DEA model is,

$$\underset{\phi,\lambda}{Max}\phi_{m,}$$

Subject to

$$Y\lambda \geq \phi_m . Y_m$$

$$X\lambda \leq X_m$$

$$\lambda \geq 0\ ,\ \phi_m \text{ free.}$$

Where ϕ is the efficiency measure

$Y = [Y_1, Y_2, \ldots Y_N]$ is the vector of all outputs.

$X = [X_1, X_2, \ldots X_N]$ is the vector of all inputs.

Y_m is the output of mth DMU

X_m is the input of mth DMU.

$\lambda = [\lambda 1, \lambda 2 \ldots\ldots \lambda N]$ is the vector of weights.

By solving the above CCR model, one can get the efficiency score (ϕ value) and the weights (λ) for each DMU.

A DMU is said to be efficient if $\phi=1$ and there is no slack. A D.M.U is said to be inefficient if $\phi<1$.

3.2.2. Tobit regression model:

The tobit regression model belongs to a family of regression models which is used to estimate the bounded dependent variable by using the continuous independent variables.

The model is ,

ISSN 2515-8260 Volume 09, Issue 8, 2022

$y_i^* = X_i^T.\beta + \in_i, i = 1, 2.....n.$

Where $\in_i$ are random errors and X_i s are explanatory variables and y_i^* is a latent response variable. The regression is obtained by ,

$y_i = \max(y_i^*, 0), i = 1, 2....n$

4. Analysis and Interpretation:

Descriptive measures and DEA analysis has been performed to assess the characteristic and efficiency of the 36 Indian states/UTs and presented in this section.

4.1. Descriptive Analysis:

Descriptive measures help us to summarize the data's characteristics. The following table presents the descriptive measures of the collected inputs and outputs of the COVID -19 data.

Table 4.1.
Descriptive Statistics

Measures	No. of Recovered Cases _Output	No.of_hospital _ Input 1	Total_Testing Input 2	Confirmed_Cases_ Input 3
Min.	3633	13	72410	4767
Max.	4826371	17103	44950523	5378452
Mean	588168.78	1924	9724483.72	693485.08
S.D.	891422.355	3345.893	11071690	1020380.672

It is observed from the above table that out of 24965463(total number of confirmed cases), 84% (Total recovered cases = 21174076) of the patients were recovered from covid 19 disease till May 2020. On average, India takes the 9724484 covid test with S.D. = 11071690.

The average value of the input 3(confirmed cases) is 693485.08 with S.D.= 1020380.672

4.2. CCR Efficiency Score:

The following table shows the CCR Efficiency Score and status of 36 D.M.U's.

ISSN 2515-8260 Volume 09, Issue 8, 2022

Table 4.2.
CCR Efficiency Score

D.M.U. No.	State/UT	CRS - Efficiency Score (ϕ)	Status
1	Andaman and Nicobar Islands	**1.000**	Efficient
2	Andhra Pradesh	0.904	Inefficient
3	Arunachal Pradesh	0.947	Inefficient
4	Assam	0.908	Inefficient
5	Bihar	0.927	Inefficient
6	Chandigarh	**1.000**	Efficient
7	Chhattisgarh	0.954	Inefficient
8	Dadra and Nagar Haveli and Daman and Diu	**1.000**	Efficient
9	Delhi	**1.000**	Efficient
10	Goa	0.976	Inefficient
11	Gujarat	0.900	Inefficient
12	Haryana	0.921	Inefficient
13	Himachal Pradesh	0.812	Inefficient
14	Jammu and Kashmir	0.825	Inefficient
15	Jharkhand	0.923	Inefficient
16	Karnataka	0.766	Inefficient
17	Kerala	0.864	Inefficient
18	Ladakh	0.953	Inefficient
19	Lakshadweep	0.809	Inefficient

20	Madhya Pradesh	0.921	Inefficient
21	Maharashtra	**1.000**	Efficient
22	Manipur	0.874	Inefficient
23	Meghalaya	0.841	Inefficient
24	Mizoram	0.800	Inefficient
25	Nagaland	0.824	Inefficient
26	Odisha	0.893	Inefficient
27	Puducherry	0.845	Inefficient
28	Punjab	0.877	Inefficient
29	Rajasthan	0.821	Inefficient
30	Sikkim	0.770	Inefficient
31	Tamil Nadu	0.906	Inefficient
32	Telangana	0.952	Inefficient
33	Tripura	0.925	Inefficient
34	Uttar Pradesh	0.942	Inefficient
35	Uttarakhand	0.754	Inefficient
36	West Bengal	0.941	Inefficient
Mean		**0.897**	

The above table reveals that out of 36 D.M.U's, 5 D.M.U's are efficient and the remaining 31 D.M.U's are inefficient.

Andaman and Nicobar Islands, Chandigarh, Dadra and Nagar Haveli and Daman and Diu, Delhi and Maharashtra were found to be efficient states/Uts in increasing the recovery rate COVID -19 affected patients. The remaining states/UTs are relatively inefficient in recovering the COVID -19 affected patients. It is also found that there is slack in the utilization of the number of hospitals in inefficient states/DMU.

4.3. Peers and Peer Weights:

The following table 4.3. presents the peers and peer weights of the 31 inefficient states/UTs.

ISSN 2515-8260 Volume 09, Issue 8, 2022

Table 4.3.
Peers and Peer Weights

DMU No.	State/UT	Peers	Peer Weights	Output Target
2	Andhra Pradesh	8 , 9	λ8= 15.79, λ9=3 0.922	1345092.047
3	Arunachal Pradesh	9 , 1	λ9= 0.012, λ1= 0.751	20543.118
4	Assam	9 , 1	λ9=0.151,λ1= 17.938	310178.712
5	Bihar	9 , 1	λ9=0.151,λ1= 66.901	617791.927
7	Chhattisgarh	21, 8, 9	λ21=0.093, λ8= 1.845, λ9=0.283	835753.689
10	Goa	6 , 21	λ6= 0.371, λ21= 0..019	108150.471
11	Gujarat	9 , 1	λ9=0.3714,λ1= 35.635	709932.663
12	Haryana	8 , 9	λ8=14.812, λ9= 0.397	649064.461
13	Himachal Pradesh	8, 9	λ8=6.785, λ9= 0.068	149006.427
14	Jammu and Kashmir	1 , 9	λ1=3.586, λ9= 0.159	230100.587
15	Jharkhand	9 , 1	λ9= 0.168 , λ1=12.403	297406.666
16	Karnataka	8 , 9	λ8= 19.138, λ9=1.450	2065861.782
17	Kerala	8, 9 , 21	λ8=0.000, λ9= 0.353, λ21= 0.107	1968018.654
18	Ladakh	9 , 1	λ9= 0.012, λ1= 0.055	15461.507
19	Lakshadweep	1, 9	λ1= 0.118 , λ9=0.003	4488.104
20	Madhya Pradesh	8, 9	λ8=14.533, λ9=0.425	683850.901
22	Manipur	9 , 1	λ9= 0.026, λ1= 0.478	37364.467

23	Meghalaya	9, 1	λ9= 0.013,λ1= 0.695	21976.214
24	Mizoram	1 , 9	λ1= 0.786,λ9= 0.003	8357.42
25	Nagaland	9 , 8	λ9=0.005, λ8= 1.193	16711.409
26	Odisha	9, 1	λ9= 0.393, λ1=9.838	575982.094
27	Puducherry	21 , 9 , 6	λ21= 0.003 ,λ9=0.041 ,λ6=0.187	77736.879
28	Punjab	9 , 1	λ9= 0.329 , λ1=5.881	468074.415
29	Rajasthan	8 , 9	λ8= 26.542, λ9= 0.435	801645.5
30	Sikkim	8 , 9	λ8= 0.845,λ9= 0.002	10527.798
31	Tamil Nadu	9, 1	λ9= 1.078 , λ1=14.467	1502716.869
32	Telangana	9 , 1	λ9=0.264, λ1= 24.437	498782.066
33	Tripura	9 , 1	λ9= 0.025 ,λ1=0.863	38730.961
34	Uttar Pradesh	9 , 1	λ9= 0.780 ,λ1=80.614	1528094.987
35	Uttarakhand	9, 1	λ9= 0.198 ,λ1=1.744	270051.723
36	West Bengal	8 , 9	λ8=64.115 , λ9=0.374	1050303.952

The inefficient States/UT's can improve their efficiency by referring to the corresponding peer states and weights.

4.3. Tobit Regression_Variables affecting the Efficiency Score:

The tobit regression model has been used to find the factors influencing the efficiency score on Indian states. The following table shows the result of the tobit regression model.

Table 4.3.

Results of Tobit regression

	Estimate	S.E.	Z Value	P>Z
(Intercept)	8.897e -01	1.495e-02	59.526	< 2e -16 *
Recovered cases	8.116e -07	2.446e -07	3.318	0.000905*
No. of hospitals	-9.252e-07	6.080e-06	-0.152	0.879051

No. of testing	-1.000e09	2.843e-09	0.352	0.725028
Confirmed cases	- 6.437e-07	1.879e-07	-3.425	0.000615*
Recovered cases	8.116e -07	2.446e -07	3.318	< 2e -16 *
Wald Statistic	14.7	.005*		

*is significant at 1% level

The above table summarizes the efficiency drivers of the Indian states health care systems using the tobit regression analysis. It is observed from the above table that there is a significant positive impact of recovered cases on the efficiency score at 1% level. That is, the inefficient can attain the efficiency by increasing the recovered cases.And also it is noted that there is a significant negative impact of confirmed cases on the efficiency scores. That is the states will become more efficient by decreasing the total confirmed cases by implementing the protocols, creating awareness etc by the state governments.It is also observed that there is an insignificant negative impact of no. of testing, no. of hospitals on the overall efficiency scores.

5. **Summary and Conclusion:**

In this study, we have considered 36 health care systems for finding the efficiency of recovery rate of COVID – 19 affected persons using D.E.A. The period considered for this study is Feb'2020 to May 2021. The CCR – DEA model is used to assess the performance efficiency of 36 states health care system in respect of COVID – 19 recovery rates. The empirical investigation results, out of 36 states, 5 states are efficient in maximizing the recovery rate of COVID – 19 affected persons. On a whole the average rate of recovery is 89% during the period Feb'2020 to May 2021. The inefficient states can improve their performance efficiency by referring to their peer states. The tobit regression model showed that there is a positive impact of recovered cases and negative impact of confirmed cases on the overall efficiency score. The inefficient states can level up their efficiency scores by maximizing recovery rate and minimizing the confirmed cases by implementing the strategies like the efficient states.

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