COVID-19 Response Efficiency Rating in Central Visayas, Philippines: A Data Envelopment Analysis Approach

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Abstract

The Philippines has been confronting a tremendous problem in its COVID-19 response. The country has adopted measures such as lockdowns, travel restrictions, and forced wearing of masks to stop the spread of the illness. The objective of the study is to determine the efficiency rating among different provinces in Central Visayas based on the number of COVID-19 facilities, government expenditures, and bed capacity as main inputs and COVID-19 cases and mortality rate as main outputs. The research made use of document analysis and desktop search in the data collection process and used the Constant-Return-to-Scale Data Envelopment Analysis model in the analysis. The results indicate that the efficiency rating of Bohol, Cebu, and Negros Occidental is 13.07%, 7.47%, and 19.53% respectively. The results also showed that Siquijor has the highest technical efficiency and is the frontier for COVID-19 response in Central Visayas.

Keywords
Efficiency, COVID-19, Data Envelopment Analysis, COVID-19 Response

1. Introduction
The world economy and health have both been significantly impacted by the COVID-19 pandemic. The reaction to the pandemic has varied across nations, despite the efforts of governments and health groups. The effectiveness of decision-making units (DMUs), such as nations or provinces in a particular decision-making problem is assessed using the non-parametric approach known as data envelopment analysis (DEA). DEA has been used in the framework of COVID-19 to assess how effectively nations have responded to the pandemic. According to a review of the literature on DEA studies on COVID-19 response, DEA can provide a thorough assessment of a nation's COVID-19 response by considering a variety of inputs, including health resources, economic resources, and policy measures, as well as a variety of outputs, including the number of cases, deaths, hospitalizations, and economic impact.

1.1 Objectives
The purpose of this study is to assess the effectiveness of COVID-19 interventions in Region VII, Philippines and to pinpoint best practices and areas for development in stopping the virus's transmission and lessening its negative effects on society. Specifically, this study aims:

1. To determine the number of hospital beds, facilities, government spending, % case per population, number of cases, number of COVID-19 deaths, and deaths-to-cases ratio among different provinces in Central Visayas, Philippines
2. To quantify the efficiency rating of each province related to COVID-19 responses

3. To evaluate benchmark items that can be applied to different provinces based on the efficiency rating

2. Literature Review

COVID-19 Response Efficiency

Studies on the effectiveness of COVID-19 responses frequently evaluate several variables, including the speed of vaccine rollouts, the capacity to contain the virus, the accessibility of medical resources and supplies, the degree of community compliance with measures like wearing masks and social isolation, and the overall effects of the pandemic on health and the economy (World Health Organization, 2023). Studies have revealed that nations with an effective COVID-19 response were able to contain the virus' transmission, cut the number of cases and fatalities, and lessen the pandemic's effects on the economy. On the other hand, nations with ineffective responses have failed to contain the virus's spread and have seen a larger number of cases and fatalities (Guzzetta et al. 2022; OECD 2022). The effectiveness of COVID-19 reactions has also been examined in research in relation to the effects of various governmental measures, such as lockdowns and travel restrictions. These studies have demonstrated that while implementing tight and consistent procedures can effectively stop the spread of the virus, doing so comes with enormous financial and societal consequences (Hale et al. 2020; Cheng et al. 2020;). Research on the effectiveness of COVID-19 responses emphasizes the significance of a coordinated and effective reaction in halting the virus's transmission, safeguarding public health, and minimizing the pandemic's effects on society and the economy (Lazarus et al., 2020; Haug et al., 2020).

Data Envelopment Analysis as a Measure for COVID-19 Response Efficiency

The effectiveness of decision-making units (DMUs), such as nations, in a particular decision-making problem is assessed using the non-parametric approach known as data envelopment analysis (DEA). DEA has been used in the framework of COVID-19 to assess how effectively nations have responded to the epidemic (Béland et al., 2020; Dialante et al. 2020; Seddighi et al. 2022). (Mahanta et al. 2022) emphasize that DEA can provide a thorough assessment of a nation's COVID-19 response by considering a variety of inputs, including health resources, economic resources, and policy measures, as well as a variety of outputs, including the number of cases, deaths, hospitalizations, and economic impact. According to DEA studies, different nations' COVID-19 responses differ in terms of their strengths and weaknesses, and the effectiveness of a COVID-19 response can be influenced by several variables, including the degree of political commitment, the accessibility of medical resources, and the cooperation of the general public (Malik et al. 2020; Kamel and Mousa 2021; Ghasemi and Boroumand 2020; Lupu & Tiganasu 2022). Additionally, the effectiveness of COVID-19 responses from various nations has been compared using DEA, giving policymakers useful information on best practices and areas for development (Min & Joo 2022). In conclusion, DEA has been widely used in the evaluation of COVID-19 responses and has been shown to provide a comprehensive and objective assessment of a country's performance in controlling the spread of the virus and mitigating the impact of the pandemic (Nepomuceno et al. 2020)

3. Methods

Scope and Limitations of the Study

This research is intended for describing the efficiency rating of Central Visayas Region in the Philippines using Data Envelopment Analysis. The selection of inputs and outputs was benchmarked from study of KK Mohanta, et. al.in the research entitled “Efficiency analysis in the management of COVID-19 pandemic in India based on data envelopment analysis” and the research of Y.E. Rays from the Turkish of Computer and Mathematics entitled “Data Envelopment Analysis and Malquimist Application: Efficiency of Primary Health Care in Morrocco and COVID-19. The research is conducted from December 2022 to February 2023.

Statement of Assumptions

The following are some of the research assumptions commonly made in DEA:

1. Linearity - DEA assumes that the relationship between inputs and outputs is linear. This means that a change in inputs will result in a proportional change in outputs.
2. Constant Returns to Scale (CRS) - DEA assumes that the DMUs operate under CRS conditions, meaning that increasing all inputs by the same proportion will result in a proportional increase in outputs.
3. Additivity - DEA assumes that the contributions of inputs to outputs are additive, meaning that the total contribution of all inputs to the outputs is equal to the sum of the contributions of each input.
4. DEA assumes that the DMUs being evaluated are homogeneous, meaning that they have similar characteristics and face similar conditions.

5. Availability of Data - the data gathered are report from the Department of Health COVID-19 tracker.

Research Environment
The research environment for studying Data Envelopment Analysis (DEA) for COVID-19 response includes the following elements:

1. Data Availability - the availability of relevant and reliable data on COVID-19 response, such as cases, deaths, healthcare capacity, and mitigation policies, is critical for conducting a DEA study. The data gathered from the study ranges from January 2019 to December 2022 which were collected through web search and document analysis from reports and articles.
2. Research Objectives - the objective of this research is the determination of efficiency rating among different provinces in Central Visayas, Philippines which includes:
   - Bohol
   - Cebu
   - Negros Oriental
   - Siquijor
3. Expertise - the researcher has basic expertise and knowledge in DEA methodology, data analysis, and to ensure the validity and reliability of the results.
4. Ethical Considerations - this study adheres to ethical considerations, such as protecting the privacy of individuals and ensuring that the results are used in a responsible manner.

Research Instruments
This research utilized the DEAP Version 2.1 software developed by The University of Queensland School of Economics written by Tim Coelli, DEAOS software, and DEAFrontier in the analysis.
Research Procedures
The research procedures for conducting a DEA study on the efficiency of COVID-19 response involve data collection, definition of inputs and outputs, selection of DEA model, calculation of efficiency scores, interpretation of results, and validation of results.

4. Data Collection
The data are collected from the Philippines COVID-19 Tracker which is a dashboard created by the Department of Health. The data gathered are from the report from January 2019 to December 2022.

5. Results and Discussion

5.1 Numerical Results
In Data Envelopment Analysis (DEA), input levels refer to the number of resources used by a Decision-Making Unit (DMU) in the production process. In the case of COVID-19 response per province in Central Visayas, the input levels could be number of beds, COVID-19 facilities, and government expenditure. In the context of each province in Central Visayas dealing with COVID-19 cases, the output levels could be the number of COVID-19 cases, the number of COVID-19 deaths, and the percentage of deaths per case. The number of COVID-19 cases represents the demand for the hospital's services, while the number of COVID-19 deaths reflects the effectiveness of the hospital's care in saving lives. The percentage of deaths per case provides a measure of the hospital's overall performance in treating COVID-19 patients, as it reflects the ratio of deaths to cases. All three outputs are important in determining the efficiency of the hospital. A high number of cases can put pressure on the hospital's resources, while a high number of deaths can indicate a need for improvement in the quality of care. The percentage of deaths per case provides a more comprehensive view of the hospital's performance, as it considers both the demand for the hospital's services and its ability to save lives.

Table 1. Input Levels per DMU

(data from DOH COVID-19 tracker as of 2022)

DMUs	INPUTS		
	No. of hospital beds (as of 2020)	COVID-19 Facilities	Estimated Government Expenditure (In millions Php)
Bohol	1163	27	700
Cebu	22773	65	2,700
Negros Oriental	1220	20	50
Siquijor	98	2	2.5

Table 2. Output Levels per DMU

(data from DOH COVID-19 tracker as of 2022)

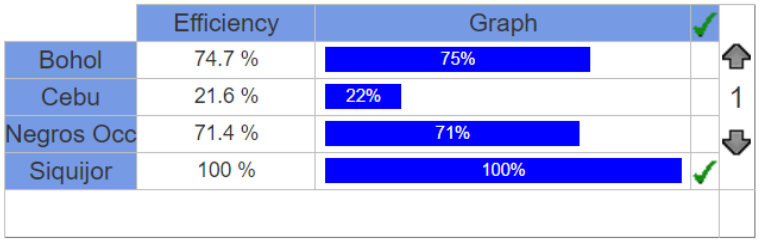
DMU	Output		
	Cases	Death	% Death per case
Bohol	26885	591	0.022
Cebu	152487	5248	0.034
Negros Oriental	26953	746	0.028
Siquijor	3034	43	0.014

5.2 Graphical Results (11 font)

In scenario 1 (Figure 1), the researcher would like to determine the efficiency rating of the DMUs with COVID-19 Facilities and number of hospital beds as inputs, and COVID-19 cases & death rate per case as output using the DEAOS software.

Figure 1. DEA Scenario 1

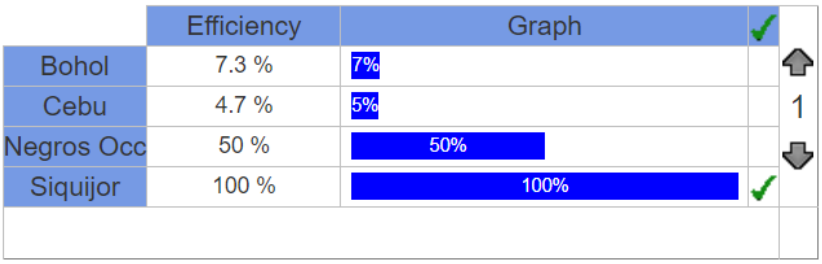
(Input = COVID-19 Facilities & hospital beds, Outputs = COVID-19 cases & death rate)



In scenario 2 (Figure 2), the researcher would like to determine the efficiency rating of the DMUs with COVID-19 Facilities and number of hospital beds as inputs, and COVID-19 cases & death rate per case as output using the DEAOS software.

Figure 2. DEA Scenario 2

(Input = Government Expenditure, Outputs = COVID-19 cases & death rate)



To determine the overall technical efficiency of the DMUs with the inputs and outputs stated in tables 1 and 2, the researcher utilized the DEAFrontier software for the analysis.

Figure 3. Overall Efficiency Rating

	DMU	Score	No# of hospil beds (as of	Covid Facilit {I}{V}	Gove Spen {I}{V}	Cases {O}{V	Death {O}{V	% Death per case {O}{V	Benchmarks
1	Bohol	13.07%	1.00	0.00	0.00	0.00	0.00	1.00	4 (1.55)
2	Cebu	7.47%	0.00	1.00	0.00	0.00	0.00	1.00	4 (2.43)
3	Neg Occ	19.53%	0.00	1.00	0.00	0.00	0.00	1.00	4 (1.95)
4	Siquijor	100.00%	0.00	0.00	1.00	1.00	0.00	0.00	

DEA can be used to determine which levels of input and output should be checked or benchmarked from the DMU/ DMUs with the highest technical efficiency.

Figure 4. Benchmark Values

	DMU	Score	{S} No# of hospil beds	{S} Covid Facilit {I}	{S} Gove Spen {I}	{S} Cases {O}	{S} Death {O}	{S} % Death per case {O}
1	Bohol	13.07%	0.00	0.43	05.77	0.66	0.63	0.00
2	Cebu	7.47%	63.57	0.00	50.59	2.12	2.20	0.00
3	Neg Occ	19.53%	46.87	0.00	36.80	1.05	1.05	0.00
4	Siquijor	100.00%						

In a Data Envelopment Analysis (DEA) study, the results are usually presented in the form of a frontier that separates efficient and inefficient Decision-Making Units (DMUs). The frontier represents the maximum level of output that can be achieved by a DMU for a given level of inputs, or the minimum level of inputs required to achieve a given level of output. The DEA results could show a frontier that separates the efficient and inefficient hospitals, based on the relationship between their inputs and outputs. Efficient hospitals would be those that lie on or near the frontier, as

they are able to produce a given level of output with fewer inputs or produce a higher level of output with the same inputs, compared to the inefficient hospitals. In addition to the frontier, the DEA results could also provide a technical efficiency score for each hospital, which reflects the extent to which the hospital is operating efficiently compared to the frontier. A score of 1 indicates that the hospital is operating at the frontier and is technically efficient, while a score less than 1 indicates that the hospital can improve its efficiency by reducing its inputs or increasing its outputs.

Based on the result of the analysis for Scenario 1 , Cebu (Efficiency Rating = 21.6%), Bohol (Efficiency Rating = 74.7%), and Negros Occidental (Efficiency Rating = 71.4%) should consider increasing their facility utilization and decrease government expenditure. The same results are also shown in Scenario 2. However, the emphasis on scenario 2 is that the gap between the output and input is high. For the benchmarking values in Figure 4, Cebu and Negros Occidental lag behind the other DMUs in terms of government expenditure and number of hospital beds relative to the population and number of cases.

5.3 Proposed Improvements

To improve COVID-19 response efficiency of the components of the Central Visayas region in the Philippines, the following recommendations are made:

For Cebu

- The government expenditure should be controlled by either reduction of up to 50.59% or increasing the hospital beds by 63.57%.

For Bohol

- The government expenditure should be controlled by reduction of up to 5.77%.

For Negros Occidental

- The government expenditure should be controlled by either reduction of up to 36.80% or increasing the hospital beds by 46.87%.

As secondary recommendations, the researchers would like to explore other factors that may affect efficiency levels of the COVID-19 response such as the number of health workers, number of policies implemented for COVID-19 Response, population density, patient-to-doctor ratio, and more.

6. Conclusion

Tables 1 and 2 outlined the different output and input levels as defined by the first objective of this research. Based on the DEA results, it has been found that Bohol, Cebu, and Negros Occidental are not operating at maximum efficiency. The results indicate that Cebu has the lowest technical efficiency of 7.47% followed by Bohol with technical efficiency of 13.07% and then Negros Occidental with technical efficiency of 19.53%. Also, for the third objective, recommendations are made under 5.3. Proposed Improvements for each component of Central Visayas, Philippines.

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Biography

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