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Covid-19: Analysis of the Efficiency of Brazilian Federative Units in Pandemic Control

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Artigos

Covid-19: Analysis of the Efficiency of Brazilian Federative Units in Pandemic Control

Covid-19: Análise da Eficiência das Unidades Federativas Brasileiras no Controle da Pandemia

Covid-19: Análisis de la eficiencia de las unidades federativas brasileñas en el control de la pandemia

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Resumo:

Objetivo da pesquisa: Este estudo tem o objetivo geral de medir o desempenho (eficiência) das unidades federativas brasileiras no controle da pandemia de Covid-19 e mitigação do número de mortes. Para tal, foram analisadas duas perspectivas, tendo sido definidos os seguintes objetivos específicos: (i) medir a eficiência para controlar a propagação da pandemia; e (ii) medir a eficiência para minimizar os óbitos.
Enquadramento Teórico: Este artigo fundamenta-se na literatura referente à gestão pública da pandemia de Covid-19 pelas Unidades Federativas Brasileiras.
Metodologia: Para o atingir ao objetivo proposto, foi realizado um estudo quantitativo, descritivo e exploratório por meio da metodologia *Data Envelopment Analysis*, nos meses de agosto e novembro de 2020. A população é composta pelas 27 Unidades Federativas Brasileiras.
Resultados: Os principais resultados informam que o isolamento social e a transparência das informações disponibilizadas à população, auxiliam na redução da propagação da doença e minimização do número de óbitos.
Originalidade: Este estudo se diferencia dos demais haja vista que, inobstante à importância da análise do desempenho governamental no contexto de epidemias, cabe destacar que não foram encontradas na literatura (pesquisa efetuada nas bases dados Web of Science, Periódicos Capes, Google Acadêmico, Spell, BDTD, base de dados ANPAD e buscador Google) pesquisas desenvolvidas com o objetivo de medir a eficiência das unidades federativas brasileiras no episódio da Covid-19, por meio de DEA.
Contribuições teóricas e práticas: Este estudo contribui para a literatura ao passo que investiga a eficiência/ineficiência da ação governamental na pandemia de Covid-19. De acordo com as análises, os resultados da ineficiência em prevenir a propagação do coronavírus e redução de mortes, podem contribuir para a definição de ações e tomada de decisões por parte dos gestores na minimização dos efeitos da epidemia.

Palavras-chave: SARS-CoV-2, resposta governamental, Data Envelopment Analysis.

Resumen:

Objetivo de la investigación: Este estudio tiene como objetivo general medir el desempeño (eficiencia) de las unidades federativas brasileñas en el control de la pandemia de Covid-19 y en la mitigación del número de muertes. Para lograr el objetivo general, se analizaron dos perspectivas y se definieron los siguientes objetivos específicos: (i) medir la eficiencia para controlar la propagación de la pandemia; y (ii) medir la eficiencia para minimizar las muertes.
Marco teórico: Este artículo se basa en la literatura sobre la gestión pública de la pandemia del Covid-19 por parte de las Unidades Federales de Brasil.

Metodología: Para lograr el objetivo propuesto, se realizó un estudio cuantitativo, descriptivo y exploratorio utilizando la metodología de Análisis Envolvente de Datos en agosto y noviembre de 2020. La población está compuesta por las 27 unidades federativas brasileñas.
Resultados: Los principales resultados indican que el aislamiento social y la transparencia de la información disponible para la población ayudan a reducir la propagación de la enfermedad y a minimizar el número de muertes.
Originalidad: Este estudio se diferencia de otros, dado que, a pesar de la importancia de analizar el desempeño gubernamental en el contexto de las epidemias, cabe destacar que no se encontraron estudios en la literatura (investigaciones realizadas en las bases de datos Web of Science, Periódicos Capes, Google Acadêmico, Spell, BDTD, base de datos ANPAD y motor de búsqueda Google) que tuvieran como objetivo medir la eficiencia de las unidades federales brasileñas en el episodio Covid-19 utilizando el DEA.
Contribuciones teóricas y prácticas: Este estudio contribuye a la literatura investigando la eficiencia/ineficiencia de la acción gubernamental en la pandemia de Covid-19. De acuerdo con los análisis, los resultados de la ineficacia en la prevención de la propagación del coronavirus y la reducción de las muertes, pueden contribuir a la definición de acciones y a la toma de decisiones por parte de los gestores para minimizar los efectos de la epidemia.
Palabras clave: SARS-CoV-2, respuesta del gobierno, Data Envelopment Analysis.

Abstract:

Research Purpose: This study has the general objective of measuring the performance (efficiency) of Brazilian federative units to control the Covid-19 pandemic and mitigate the number of deaths. In order to meet the general objective, two perspectives were analyzed, with the following specific objectives being defined: (i) to measure the efficiency to control the spread of the pandemic; and (ii) to measure the efficiency to minimize deaths.
Theoretical framework: This article is based on the literature regarding the public management of the Covid-19 pandemic by the Brazilian Federal Units.
Methodology: To achieve the proposed objective, a quantitative, descriptive, and exploratory study was conducted using the Data Envelopment Analysis methodology in August and November 2020. The population is composed of the 27 Brazilian Federative Units.
Results: The main results report that social isolation and transparency of information made available to the population assist in reducing the spread of the disease and minimizing the number of deaths.
Originality: This study differs from others because, despite the importance of analyzing governmental performance in the context of epidemics, it is worth noting that no studies were found in the literature (research conducted in Web of Science, Periódicos Capes, Google Scholar, Spell, BDTD, ANPAD database and Google search engine) that aimed to measure the efficiency of Brazilian federal units in the Covid-19 episode using DEA.
Theoretical and practical contributions: This study contributes to the literature by investigating the efficiency/inefficiency of government action in the Covid-19 pandemic. According to the analysis the results of inefficiency in preventing the spread of the coronavirus and reduction of deaths, can contribute to the definition of actions and decision making by managers in minimizing the effects of the epidemic.
Keywords: SARS-CoV-2, government response, Data Envelopment Analysis.

INTRODUCTION

The Covid-19 pandemic represents one of the greatest challenges for global health in the 21th century. Factors that exacerbate the challenges to face the pandemic include insufficient scientific knowledge regarding the new coronavirus, rapid spreading of the disease, and high death rate among vulnerable populations and groups (Barreto, Barros, Carvalho, Codeço, Hallal, Medronho, Struchiner, Victora, & Werneck, 2020), which hampers government decision making regarding the implementation of effective strategies to mitigate the spread of the disease and the number of deaths.

The Brazilian scenario in facing the pandemic is even more adverse for the serious socioeconomic problems that the country had before the detection of the first case of Covid-19 on February 26, 2020. Besides this scenario, the country has a territory of continental proportions, with different population distribution patterns and quite heterogeneous local realities.

Thus, during the first months of 2020, governors of the states of the Brazilian federation and the Federal District were challenged to propose effective actions to minimize the spread of Covid-19 and reduce its consequences regarding the number of deaths, as well as to mitigate the post-pandemic economic effects.

Actions such as the creation of hospital infrastructure and intensive care unit (ICU) beds, provision of personal protective equipment (PPE's) for health, management, and outpatient care professionals, provision of a technical team of health professionals, medicines, and respirators, among others; as well as actions that are not agreed by all citizens, such as social isolation and legislation that requires the use of protective masks in public, were conducted.

According to Moon (2020); Laegreid (2020) and Dai, Di Ful, Meng, Liu and Liu (2020), a transparency policy in the communication of risks associated with the disease, voluntary cooperation by citizens, detailed information on Covid-19, and pragmatic decision making are critical factors to fight the pandemic.

Thus, several measures to contain the spread of the new coronavirus and mitigate the number of deaths were sanctioned by the local authorities in the three public spheres, with the most widespread measure being the practice of social distancing (Bezerra, Silva and Soares; 2020), widely known as social isolation by the Brazilian population, which was the term chosen to be used in this study.

Considering the perspective of the need to evaluate the efficiency of the actions taken in face of the Covid-19 pandemic, this study sought to answer the following question: Which Brazilian federative units were more efficient in controlling the dissemination of Covid-19 and in minimizing the number of deaths?

Thus, this study has the general objective of measuring the performance (efficiency) of Brazilian federative units to control the Covid-19 pandemic and mitigate the number of deaths. In order to meet the general objective, two perspectives were analyzed, with the following specific objectives being defined: (i) to measure the efficiency to control the spread of the pandemic; and (ii) to measure the efficiency to minimize deaths.

This study is justified based on the context highlighted by Duan, Jiang, Deng, Zhang and Wang (2020) that government intervention has an impact, whether positive or negative, in the prevention and control of epidemic transmission and in the number of deaths.

Thus, the analysis of government performance in the context of epidemics is extremely relevant, especially in the current case in which the Covid-19 epidemic is still ongoing. The success or failure of the State in this scenario determines its success to accomplish its primary functions, conferred by the 1988 Brazilian Constitution, of being an agent that promotes social welfare and protects its citizens.

Despite the importance of analyzing governmental performance in the context of epidemics, studies developed with the objective of measuring the efficiency of Brazilian federative units in the Covid-19 episode through Data Envelopment Analysis were not found in the literature (research conducted in the databases of Web of Science, Capes Journal Portal, Google Scholar, Spell database, BDTD - Theses and Dissertations Bank from USP, ANPAD database, and Google searcher).

By reaching the proposed objective, this study contributes to the analysis of the effectiveness of the State in the context of the triple crisis (economic, social, and behavioral) caused by the pandemic of the new coronavirus. Thus, the contribution of the study is based on the construction of models to evaluate the performance of Brazilian federative units in the management of the Covid-19 pandemic through surveying indicators of efficiency and through theoretical research addressing the empirical aspect, so that the analysis models can be replicated or complemented in the future.

The article begins with the history of the Covid-19 pandemic in the world and in Brazil, then going on to deal with previous studies on the subject. Subsequently, the work details the variables used in the construction of the model. The theoretical discussion and the gaps left by the analyzed articles support the adopted model. Finally, the contributions of the study, its limitations and challenges for future studies are summarized.

Overview of the Covid-19 pandemic

In December 2019, hospitals in Wuhan, the capital of the People's Republic of China province of Hubei, a major Chinese transportation hub, began receiving local patients with severe pneumonia of unknown origin. Many patients had only the exposure to the Huanan seafood wholesale market, which also sells live wild animals, as common factor (Singhal, 2020).

Still according to the author cited above, on December 31, 2019, China notified the outbreak of pneumonia of unknown etiology to the World Health Organization (WHO). On January 7, the virus was identified as a coronavirus, which is a virus with crown-shaped structure that, in general, circulates only between animals, such as rodents and bats, but infects people when there is close coexistence or the virus mutates (Dogra, Goyal and Sharma, 2020).

When the first studies on the new coronavirus appeared, after the occurrence of the first cases in Wuhan province, the pathogen was given the provisional name "2019 n-CoV" and later the official name "SARS-CoV-2", an acronym for the full name in English, *Severe Acute Respiratory Syndrome Coronavirus 2*. In several localities in the world, the most used terms to refer to the pathogen are Covid-19 or new coronavirus, expressions also used in this study.

Since the notification by Chinese authorities of the first occurrences in December 2019 to the WHO, the number of cases in that moment began to increase exponentially, some of which were not contaminated in the Huanan seafood market, suggesting the occurrence of transmission among humans (Singhal, 2020). The first fatal case was reported to the WHO on 11 January 2020.

As a result of the Chinese New Year, the massive displacement of the Chinese spread the epidemic to other locations, with cases being reported in other provinces of China and in other countries, such as Thailand, Japan, and South Korea, in very rapid succession. Transmission to healthcare professionals who treated patients infected with Covid-19 was described on January 20, 2020 (Jain, Choudhury, Sharma, Kumar, & Tiwari, 2020).

On January 23, 2020, the 11 million inhabitants of Wuhan were placed under travel restrictions, with entry and exit controls in the region, and these measures were subsequently extended to other cities in Hubei province. Still on January 23, 2020, cases of Covid-19 were reported in other countries by patients with no history of travel to China, suggesting that local transmission between humans was occurring in these locations (Singhal, 2020).

Airports in different countries, including India, began using screening mechanisms to detect symptomatic people returning from China; those who had some characteristic symptom of the disease, such as fever or cough, were isolated, being tested for Covid-19. Soon it became apparent that the infection could be transmitted by asymptomatic people. Thus, countries that evacuated their citizens from Wuhan via special flights or had travelers returning from China subjected all symptomatic or asymptomatic people to 14 days of isolation and tested them for the virus (Jain et al., 2020).

On January 30, 2020, the World Health Organization (WHO) declared the Chinese epidemic of Covid-19 as a public health emergency of international concern, which represents a high risk for countries with a vulnerable health system. The WHO emergency committee also informed that the spread of the disease could be mitigated by early detection, social isolation, immediate treatment, and an efficient system for tracking the contacts made by those infected (Sohrabi, Alsafi, O'neill, Khan, Kerwan, Al-jabir, Losifidis, & Agha, 2020). After the date of this declaration, the number of deaths and cases has continued to grow.

In Brazil, the first case of Covid-19 confirmed by the Ministry of Health of Brazil (MSB) occurred on February 25, 2020. A 61-year-old man who traveled to northern Italy, Lombardy region, which already had a significant number of occurrences at the time, was affected by the disease. As of March 26, 2020, there were already 2,915 confirmed cases and 77 deaths in Brazilian territory in the most diverse locations, according to official data from the Ministry of Health of Brazil (Lima, Dias, Rabelo, Cruz, Costa, Nigri, & Neri, 2020).

States like Rio de Janeiro and São Paulo registered episodes of community transmission, when it is not possible to identify the origin of the transmission.

On August 28, 2020, official data from the MSB reported 3.66 million accumulated cases of Covid-19, approximately 17,463 cases per million inhabitants, and 116,580 deaths in Brazilian territory. The total number of recovered patients was 2.85 million, and the number of patients monitored by the Brazilian health system was 705,020. The Southeast region presented the highest number of accumulated cases, 1.28 million, followed by the Northeast, North, Central-West and South regions, with 1.09 million, 513,635, 404,421, and 368,990 accumulated cases, respectively (Susanalítico, 2020).

In face of the scenario presented, the challenges faced by Brazil to reduce the spread of the Covid-19 epidemic and minimize the number of deaths caused by the disease are aggravated by the lack of knowledge on virus transmission in a context of high levels of social, economic, and demographic inequality, with populations living in precarious situations of sanitation and housing, without access to basic prophylaxis items, such as water, soap, and alcohol gel, and in situations of agglomerations, such as in communities (*favelas*) in the states of Rio de Janeiro and São Paulo with a high prevalence of chronic diseases (Barreto et al., 2020).

The Brazilian government has implemented actions that can be grouped into three major dimensions, namely: the determination or recommendation of social distancing or social isolation; the expansion of hospital infrastructure, with expansion of the service capacity of health services; and economic support to citizens, families, and businesses. Despite these actions, in the Brazilian case, implementation occurs heterogeneously from isolated actions and measures by the federative units due to the lack of coordination and articulation at national level (Pires, 2020).

Social distancing is among the countless strategies for prevention of Covid-19, which is the minimization of contact between healthy and potentially infected individuals, avoiding agglomerations and advocating a distance of at least one and a half meters between people. In extreme cases, according to the understanding of the ruler on duty, social isolation is adopted, when people must be confined in their homes for social distancing to occur (Pereira, Oliveira, Costa, Bezerra, & Pereira, 2020).

In Brazil, the first episode of social isolation occurred on March 13, 2020, when the governor of the state of Rio de Janeiro, Wilson Witzel, issued a decree that determined the closure of places that could cause agglomerations, such as schools, cinemas, and theaters, among others, as well as banning events for a period of 15 days. Only essential activities were maintained (Farias, 2020).

On March 18, 2020, the federal government declared a state of emergency and on March 20, 2020, the MSB confirmed community transmission throughout national territory. Since then, the MSB started to recommend measures of social isolation according to the peculiarities of each region and observing epidemiological criteria, i.e., when Covid-19 transmission is beyond the capacity of the Brazilian health system (Schuchmann, Schnorrenberger, Chiquetti, Gaiki, Raimann, & Maeyama, 2020)

Previous studies on Covid-19

Several studies conducted previously can be highlighted regarding the pandemic situation and its consequences in the context of the Covid-19 epidemic. Farias (2020) analyzed social isolation as a strategy to reduce the vulnerability to the advance of Covid-19. Castro, Oliveira, Morais, and Gai (2020) analyzed coping strategies against Covid-19 to reduce impacts on organizations, highlighting social isolation and restrictions on the movement of people in different countries, the best strategy to contain the spread of the disease, and how organizations began to give more attention to digital management of business and work from home in face of this reality.

Moraes (2020b) analyzed from May 25 to June 7, 2020 the legal measures for social isolation and their relation with the severity of the epidemic. The author stated that there is a decentralized policy of social

isolation in Brazil, with significant variation in the degree of rigor applied by federal units. According to the author, there were alternate periods of relaxation and increased rigor.

Corroborating the pandemic control, Antunes, Peres, Baião, Ranzani, Bastos, Silva, Souza and Marchesi (2020) presented some actions implemented by countries such as China, South Korea, Italy, Spain, and Brazil. Among actions, there were, namely: (i) social isolation; (ii) closing borders; (iii) banning the entry of passengers via airports; and (iv) quarantine. According to the results of the study, actions such as social isolation and quarantine were effective to decrease the growth rates of Covid-19 cases. The effect of measures began from one to two weeks after implementation.

Dias Jr. (2020) described how the Brazilian population supported and performed social isolation in the context of the Covid-19 pandemic. Moraes (2020a) evaluated a period of approximately four months of social isolation measures in the country, taking as reference the moment when the first measures were introduced.

In order to contribute to manager decision making in the pandemic, Fernandes, Henrique, Liebel, Dazzi and Mezadri (2020) evaluated how dashboards are being used to assist in health management during the pandemic. Through dashboards, managers can visualize the large volume of data graphically, allowing the analysis of a given situation and the management of their decisions safely and cautiously, i.e., contributing to the transparency of information and decisions.

The authors Jouzdani and Shirouyehzad (2020) conducted a study in Iran relating the contact of people and the response capacity of the health system, i.e., the available resources, such as beds, to fight the pandemic, as health system capacity is one of the most important factors affecting mortality. The following variables were used to conduct the study: (i) population susceptible to Covid-19; (ii) population infected by Covid-19; (iii) population killed by Covid-19; and (iv) population recovered from Covid-19. The population susceptible to Covid-19 represented the total number of people who would be infected and would require hospitalization.

Several previous studies can be highlighted regarding the use of the data envelopment analysis (DEA) methodology using variables related to Covid-19. Breitenbach, Ngobeni and Aye (2020) analyzed the efficiency to restrain the Covid-19 epidemic in the 31 countries with the most infections during the first 100 days of the outbreak. Ghasemi, Boroumand and Shirazi (2020) researched the efficiency of 19 countries, from February 2, 2020 to April 12, 2020, to control the spread of the pandemic and prevent deaths caused by the new coronavirus. In addition, Shirouyezad, Khodadadi-Karimvand and Jozdani (2020) studied the relative growth rate of Covid-19 contagion in the European countries most affected by the disease in the last two weeks of March 2020, verifying the evolution or involution of efficiency through the Malmquist Index (MI).

The study by Mariano, Torres, Rodriguez de Almeida, Ferraz, Rebelatto and Soares de Mello (2020) analyzed, through data envelopment analysis, the number of cases and deaths caused by coronavirus notified in Brazil in relation to the hospital infrastructure of federative units and state capitals. For this, the authors used the variables (i) number of doctors; (ii) number of respirators; (iii) number of beds; (iv) number of cases; and (v) number of deaths.

Other studies were conducted in order to analyze through DEA the efficiency of the actions implemented in China, where the first case of the new coronavirus was detected, to control the disease. The study by Duan et al. (2020) is highlighted, who examined the relationship between government interventions, risk perception, and public adoption of protective action recommendations during the emergence of the disease in mainland China.

Method

In order to achieve the proposed objective, a quantitative, descriptive, and exploratory study was conducted to analyze the efficiency of the Brazilian federative units to control the spread of Covid-19 and mitigate the number of deaths in each of the 26 Brazilian states and the Federal District (Brazilian Federative Unit - BFU) through comparison and analysis of the results using the data envelopment analysis (DEA) methodology.

The research object of this study is the Brazilian federative units, more specifically the States and the Federal District. All federative entities are endowed with autonomy in their political-administrative organization, manifested by the capacity for self-organization, self-government and self-administration, inserted in the latter, the necessary financial autonomy (Catarino & Abraham, 2018). In the states, executive power is exercised by a governor elected every four years.

The variables of this study are secondary data collected from documental information obtained from the following sources: (i) Hospital Information System of the Unified Health System (SIH/SUS), available at the website of the SUS Department of Informatics (DATASUS, 2021) of the Brazilian government; (ii) the Covid Radar Panel (Covidradar.org); and (iii) Transparency indexes (Transparenciacovid19, 2021); (iii) Isolation indexes (Inloco, 2021). Collected data referred to the months of August and November 2020. The period of analysis was defined as the month of August was the peak moment of the pandemic in the country and the month of November was the date of elaboration of this study.

The tool used to analyze the performance of Brazilian federative units was the data envelopment analysis (DEA). DEA generates a multivariate model, i.e., contemplating more than two variables, and was developed in order to measure the efficiency of decision making units (DMU) considering multivariate aspects (Charnes, Cooper, & Rhodes, 1978).

DEA is used to measure the relative efficiency of DMUs, which are organizations that present inputs, processing inputs, and products, establishing an efficiency frontier and measuring efficiency in relation to that frontier. Thus, a DMU is considered efficient if no other DMU produces better results using fewer inputs. Thus, when the coefficient of a DMU is one or 100%, its resources are optimized in comparison to the other DMUs under analysis.

The DEA model used in this research was the input oriented BCC DEA model (Banker, Charnes, & Cooper, 1984) in face of the regional, demographic, economic, and social discrepancy of Brazilian federative units. The model was developed to deal with variable returns of scale, replacing the paradigm of proportionality between inputs and outputs with the paradigm of convexity. The input oriented model formulated is written as follows (Mariano, 2012):

$$\text{Max} \sum_{r=1}^{m} u_r y_{rk} + u_k \qquad (1)$$

Subject to restrictions:

$$\sum_{r=1}^{m} u_r y_{rk} + u_k - \sum_{i=1}^{n} v_i x_{ik} \leq 0 \qquad (1a)$$

$$\sum_{i=1}^{n} v_i x_{ik} = 1 \qquad (1b)$$

$u_r, v_i \geq \varepsilon; u_k$ Signal-free

Where: y = products; x = inputs; u, v = weights; r = 1, ..., m; i = 1, ..., n; k = 1, ..., N; ε = non-Archimedean number.

Data Analysis

In this study, the efficiency of BFUs was measured in two phases, the first being the evaluation of performance to minimize the spread of the Covid-19 epidemic, i.e., controlling the spread, and the second, the evaluation of performance to minimize the number of deaths caused by Covid-19.

Phase I - Minimizing the spread of the Covid-19 epidemic

Phase I investigated the performance of BFUs to minimize the number of people infected by the new coronavirus, i.e., the performance of the Brazilian federative unit to control the epidemic.

The variables comprised in the analysis are shown in Chart 1:

Chart 1: Inputs and Outputs used in Phase I

Output
Number of new cases of Covid-19 - (NCC)
Inputs
Social isolation index - (SII)
Transparency Index - (TI)

Output:

Number of new cases of Covid-19 in each Brazilian state and the Federal District (NCC): Variable that presents the number of new cases of Covid-19 in the BFUs. For being an undesirable output, considering that the criterion for selecting the output is "the bigger, the better" (Leiva, dos Reis, & Orrico Filho, 2020), the 1/NCC ratio was used, which consists of a strategy to treat undesirable outputs.

Inputs:

Social Isolation Index (SII): The social isolation index is an indicator that shows the percentage of the Brazilian population in the federal units that respected the governmental determination of social isolation. It is understood that the greater the social isolation, the lower the chances of infection (Garcia and Duarte, 2020). For being an undesirable input, considering that the criterion for selecting the input is "the smaller, the better", the 1/SII ratio was used.

Transparency Index (TI): The Covid-19 transparency index is an initiative of the Open Knowledge Brasil (OKBR) to evaluate the quality of data and information available to the population regarding the pandemic. According to Fernandes et al. (2020), analysis of the information allows the public manager to make decisions securely and cautiously, besides allowing the population to acquire the knowledge required for prevention. Thus, the higher the transparency index, the better the efficiency to fight Covid-19. The 1/TI ratio was also used for this variable.

Phase II – Minimizing the number of deaths caused by Covid-19

In this phase, the efficiency of BFUs to mitigate the number of deaths caused by Covid-19 was evaluated. Dynamic DEA was used for modeling, as the output of Phase I was used as input for analysis of Phase II. The variables comprised in the analysis, according to Chart 2, are:

Chart 2: Inputs and Output used in Phase II

Output
Number of deaths caused by Covid-19 (ND)
Inputs
Efficiency level in Phase I – (EFIL) Number of respirators – (NR)

Output:

Number of deaths caused by Covid-19 (ND): The data refer to deaths by Covid-19 in BFUs in the months of August and November 2020. As this is an undesirable output, the ratio used was 1/ND.

Inputs:

Efficiency level in Phase I (EFIL): The performance to control the spread of the disease is a factor that influences the number of deaths caused by Covid-19. Thus, the result of the performance of BFUs in Phase I was used as an input in Phase II. As it is an undesirable input, the ratio used was 1/ EFIL.

Number of respirators (NR): This variable represents one of the essential resources to control the number of deaths. The health system capacity is one of the most important factors affecting the mortality rate (Jouzdani and Shirouyehzad, 2020). As this is an undesirable input, the ratio used was 1/NR.

Results and discussion

Efficiency of BFUs to control the spread of the pandemic

Descriptive statistics of the variables analyzed Descriptive statistics of the variables analyzed

The descriptive statistical analyzes of the variables studied are shown in Table 1.

Table 1: Descriptive Statistics – Data

Descriptive Statistics	Social Isolation Index – (SII)		Transparency Index – (TI)		New Cases of Covid-19 – (NCC)	
	Aug/2020	nov/20	Aug/2020	nov/20	Aug/2020	nov/20
Means	37%	46%	84	83	46,140	44,619
Standard Deviation	1%	3%	13	13	50,128	41,407

According to the results of the descriptive statistics of data from BFUs, the mean social isolation index increased from 37% to 46% in November 2020. The transparency index remained stable, with 84 and 83 points, respectively. The number of cases decreased from 46,140 to 44,610, i.e., decreasing 3.32%.

As a result, data indicated that the mean increase of the social isolation index contributed to the mean decrease in the number of cases, as that the transparency index showed similar values for both periods.

These results corroborate those obtained by Moraes (2020b). According to the researcher, the legal measures of social isolation are related to the severity of the epidemic, noting that the policy of social isolation is decentralized in Brazil, with very significant variation in the degree of rigor applied by federal units.

Efficiency level to control the spread of the pandemic

BFUs were classified according to the best result of the relationship between the number of new cases of Covid-19 (NCC) and the variables social isolation index (SII) and transparency index (TI). Table 2 shows the descriptive statistics of the results of efficiency level.

Table 2: Classification of BFUs according to efficiency level

Descriptive Statistics	Results Aug/2020	Results Nov/2020
Means	32%	48%
Standard Deviation	32%	34%

The mean efficiency level to control the spread of the pandemic was 32% in August 2020. In November of that same year, the mean efficiency level increased to 48%, i.e., the control of the spread of the pandemic improved.

Table 3 shows an overview of BFUs classified by efficiency level to control the spread of Covid-19.

Table 3: Overview of the results of efficiency level

Efficiency (E)	BFUs Aug/2020	BFUs Nov/2020
Full (E = 100%)		Amapá
	Acre	Alagoas
	Amazonas	Mato Grosso do Sul
	Rondônia	Paraná
		Roraima
Strong (80% ≤ E < 100%)	Amapá	Rondônia
Moderate (60% ≤ E < 80%)		Acre
	Mato Grosso do Sul	Sergipe
		Tocantins
Weak (E ≤ 60%)	Others – 22	Others - 18

Influenced by the improvement of the social isolation index, of the total of 27 BFUs, 22 showed efficiency level below 60% in August 2020. This number decreased to 18 in November 2020.

In August, the number of BFUs considered fully efficient was 3, rising to 5 in November 2020. BFUs with moderate efficiency level increased from 3 in August 2020 to 5 in November.

The BFU of São Paulo, although increasing by 3% its efficiency level and showing a positive variation in the social isolation index, which increased from 36% to 44%, showed the lowest efficiency level for both periods analyzed. São Paulo should target an increase of 3.91% in the social isolation index and 17.07% in the transparency index in order to be positioned under the envelopment frontier.

The results of studies by Moraes (2020a) and Fernandes et al. (2020) corroborate the results of this research, as the variables social isolation and transparency index were also analyzed in their studies related to Covid-19, stating the importance and contribution of these variables for pandemic control.

Other results generated with the use of the data envelopment analysis methodology are the information on the target values of the variables under study, i.e., what would be the ideal input values for the BFU be positioned on the envelopment frontier. The descriptive statistics of mean target values is shown in Table 4.

Table 4: Target values of variables (inputs)

Descriptive Statistics - Nov/2020	Social isolation index - (SII)		Transparecy index - (TI)	
	nov/20	Targets	nov/20	Targets
Means	46%	49%	83	89

The target value for the social isolation index is 49%, i.e., an increase of 3%. The target value for the transparency index variable is 89, with 83 being the current value.

Thus, the results of the efficiency of BFUs to minimize the number of deaths caused by the pandemic are discussed below.

Efficiency of BFUs to minimize the number of deaths caused by Covid-19

Descriptive statistics of the variables analyzed

The descriptive statistics of the variables studied are shown in Table 5.

Table 5: Descriptive Statistics - Data

Descriptive Statistics	Number of Respirators (NR)		Efficiency in Phase I (NEFI)		Deaths caused by covid-19 (ND)	
	Aug/2020	nov/20	Aug/2020	nov/20	Aug/2020	nov/20
Means	2,871	2,926	32%	48%	1,070	771
Standard Deviation	4,244	4,381	32%	34%	1,348	1,004

According to the results of the descriptive statistics of the data of BFUs, the mean number of respirators increased from 2,871 to 2,926 in November 2020, an increase of 1.91%, evidencing the effort by the states to acquire inputs for the treatment of Covid-19. The mean efficiency ratio in Phase I increased from 32% to 48%. The mean number of deaths decreased from 1,070 to 771, i.e., decreasing 27.94%, confirming the result of the efforts to increase the mean number of respirators and the efficiency to control the pandemic, evidenced by the results of Phase I.

Thus, the data indicated that the mean increase in the number of respirators and in the efficiency to control the spread of the epidemic contributed to the mean reduction in the number of deaths.

Efficiency of BFUs to minimize the number of deaths caused by Covid-19

BFUs were classified according to the best result of the relationship between the number of deaths caused by Covid-19 (NCC) and the variables number of respirators (NR) and efficiency level in Phase I (EFIL). Table 6 shows the descriptive statistics of the results of efficiency levels.

Table 6: Classification of BFUs by efficiency level

Descriptive Statistics	Results Aug/2020	Results Nov/2020
Means	75%	67%
Standard Deviation	21%	26%

The mean efficiency level to minimize deaths caused by the pandemic was 75% in August 2020. In November of the same year, the mean efficiency level increased to 67%, i.e., a reduction in the overall efficiency to minimize deaths caused by Covid-19.

As the mean efficiency to minimize the number of deaths decreased, of the total of 27 BFUs, 8 had an efficiency level below 60% in August 2020. This number increased to 11 in November 2020.

In August, the number of BFUs considered fully efficient was 8, a value that was maintained in November 2020, although only 4 BFUs were fully efficient in the two periods under study, Acre, Rio de Janeiro, Roraima, and São Paulo. There were 4 BFUs with strong efficiency level in August 2020, changing to 0 in November.

The BFU of Goiás presented the worst efficiency in August 2020 and the 6th worst result in November. In August, the target that this BFU should pursue was a 66.32% increase in its efficiency in Phase I, so that it could be positioned over the envelopment frontier and be fully efficient. The BFU increased the number of respirators by 3.56% and the efficiency to control the epidemic by 150%, but these variations were insufficient for the state of Goiás to be among the Brazilian states fully efficient in November 2020.

Table 7: Overview of results of efficiency level

Efficiency (E)	BFUs Aug/2020	BFUs Nov/2020
Full (E = 100%)	Acre Amazonas Ceará Espírito Santo Pará Rio de Janeiro Roraima São Paulo	Acre Distrito Federal Mato Grosso do Sul Minas Gerais Paraná Rio de Janeiro Roraima São Paulo
Strong (80% ≤ E < 100%)	Amapá Maranhão Pernambuco Rondônia	
Moderate (60% ≤ E < 80%)	Alagoas Mato Grosso do Sul Minas Gerais Paraná Rio Grande do Norte Rio Grande do Sul Sergipe	Alagoas Mato Grosso Pará Rio Grande do Norte Rio Grande do Sul Rondônia Sergipe Tocantins
Weak (E ≤ 60%)	Others –8	Others – 11

In November 2020, the BFU of Amazonas presented the worst result regarding relative efficiency, appearing on the list of BFUs fully efficient in August 2020. In November 2020, the BFU of Amazonas

decreased the number of respirators in the order of 1.45% in relation to August, besides significantly decreasing the efficiency to control the pandemic, in the order of 74.64%. The results indicated that the reduction in the number of respirators and the inefficiency to control the spread of the epidemic led Amazonas to significantly increase the number of deaths.

The results of studies by Ghasemi, Boroumand and Shirazi (2020) and Breitenbach, Ngobeni and Aye (2020) corroborate the results of this study, stating the importance of controlling the epidemic and of the number of equipment (respirators, in the case of this study) used in intensive care units in the treatment of patients with Covid-19 to minimize the number of deaths caused by the disease.

Other results generated with the use of the data development analysis methodology are the information of the target values of the variables under study, i.e., what would be the ideal input values for the BFU to be positioned on the envelopment frontier. The descriptive statistics of the mean target values is shown in Table 8.

Table 8: Target values of variables (inputs)

Descriptive Statistics - Nov/2020	Number of Respirators (NR)		Efficiency in Phase I (NEFI)	
	nov/20	Targets	nov/20	Targets
Means	2,872	2,951	32%	43%

The target value for the number of respirators is 2,951, i.e., an increase of 2.75%. The target value for the variable efficiency in Phase I is 43%, an increase of 34.38%.

Conclusion

The peak of the pandemic in the country during the period studied was evidenced in the month of August 2020. In this context, the research sought to analyze the efficiency of Brazilian federative units to reduce the spread of Covid-19 and mitigate deaths caused by the pandemic.

According to the analyzes, the results of the inefficiency to prevent the spread of the coronavirus and reduce deaths caused by the epidemic can contribute to the definition of actions and decision making by the managers in the management of the pandemic.

Through the methodology used, it is possible to identify in the first stage of the study the importance of social isolation and the need for effective actions by the public authorities, besides the need for awareness of the society as a whole. Transparency of information and clear communication with society on the reality of federative units are important actions to manage this situation.

Another result observed in this study is the importance of the structure of hospital units to mitigate the number of deaths and maintain life, specifically in relation to respirators. As an alert for all countries, besides maintaining a minimum structure of the health network, there is need for better management of the supply chain of hospital inputs.

In the second phase of the research, it was identified that the number of deaths is directly related to the results of Phase I, i.e., the control of contagion is directly related to the number of deaths, showing that the mortality caused by the virus can be minimized with actions related to social isolation and transparency of information provided to the population.

Regarding possible future research, it is suggested to replicate the models used in this study in other time intervals and in other countries in order to compare results, besides using other variables related to the measurement of the efficiency to manage the Covid-19 epidemic.

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