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VULNERABILITY INDEX TO COVID-19 FOR BRAZILIAN STATES

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VULNERABILITY INDEX TO COVID-19 FOR BRAZILIAN STATES

ÍNDICE DE VULNERABILIDADE PARA COVID-19 DOS ESTADOS BRASILEIROS

Abstract: This present paper brings a vulnerability index to Covid-19 for Brazilian states. The Covid-19 pandemic is the largest since the great flu of 1918 and Brazil, which already has major supply limitations in health provision, experiences additional stress to the health system caused by the excess demand caused by the pandemic. Thus, this index is composed of a weighted average of state indicators, which are HDI, Net Current Revenue per capita, health expenditure per capita, percentage of households with more than six residents, percentage of elderly population, access to basic sanitation, total population, the number of ICUs and the number of doctors and respirators per hundred thousand inhabitants. The results indicate that the states best placed in the vulnerability ranking are Federal District and São Paulo, and the states with the worst ranking being Alagoas and Amapá. In the medium term, there is an association between the number of accumulated cases and the Hospital Vulnerability Index. The same association exists, although at a lower level, between the hospital vulnerability index and the number of deaths per capita.
Keywords: COVID-19, State Vulnerability, Brazilian States, Vulnerability Index.

Resumo: O presente artigo traz um índice de vulnerabilidade para Covid-19 para os estados brasileiros. A pandemia Covid-19 é a maior desde a grande gripe de 1918 e o Brasil, que já apresenta grandes limitações de oferta de saúde, passa por um estresse adicional ao sistema de saúde causado pelo excesso de demanda causado pela pandemia. Assim, esse índice é composto por uma média ponderada dos indicadores estaduais, que são IDH, Receita Corrente Líquida per capita, Despesa com saúde per capita, percentual de domicílios com mais de seis moradores, percentual da população idosa, acesso a saneamento básico, população total , o número de UTIs e o número de médicos e respiradores por cem mil habitantes. Os resultados indicam que os estados mais bem colocados no ranking de vulnerabilidade são Distrito Federal e São Paulo, e os estados com pior posição são Alagoas e Amapá. No médio prazo, há associação entre o número de casos acumulados e o Índice de Vulnerabilidade Hospitalar. A mesma associação existe, embora em nível inferior, entre o índice de vulnerabilidade hospitalar e o número de óbitos per capita.
Palavras-chave: COVID-19, Vulnerabilidade do Estado, Estados brasileiros, Índice de Vulnerabilidade.

1. INTRODUCTION

COVID-19 started in the Chinese city of Wuhan in late 2019 and quickly spread across the world. It is the biggest pandemic since the great flu of 1918 and, after United States and India, Brazil - albeit later - became one of the global epicenters of the pandemic in mid-June.

A damage mitigation strategy implies the emergency implementation of public policies. The fatality rate of COVID-19 is still unknown and even an apparently low rate can lead to millions of deaths. Preliminary studies in the city of Wuhan have estimated this fatality rate to be 1.4% (Wu et. Al, 2020).

With the level of lethality estimated in China, the levels of infection needed for herd immunity would indicate a heavy cost in human lives. If 70% of the Brazilian population were infected, and we applied a lethality rate of 1.4% to it, in the long run Brazil would have two

million deaths. Limitations in health infrastructure, such as lack of ICU beds and respirators, can increase the lethality rate and, consequently, the death toll.

This extreme scenario would correspond, approximately, to 40 times the number of homicides in Brazil, which is 50 thousand per year. The adoption of social isolation measures and the mapping of available resources to prevent as many deaths as possible comes, therefore, as a necessary response to the prevention of this extreme scenario.

In normal times, there are notorious supply limitations in health provision in Brazil. Even under a pandemic, there is still a demand for medical provision of care for heart attacks, strokes, cancers and other illnesses that normally already require intensive care units.

Under a pandemic, there is an additional stress on the health system: the excess demand characteristic of normal times is added to an additional peak of demand due to the advent of COVID-19. It is possible, therefore, that those who need urgent medical care may die due to the lack of beds in intensive care units, due to the occupation of people contaminated by COVID-19, and vice-versa.

In the absence of a vaccine, the use of non-pharmacological interventions, such as social detachment, aims to reduce the number of infected people at a given point in time, to avoid overloading the health system. The strategy involves restricting the circulation of people to avoid contagion, waiting for the gradual immunization of the population and flattening the need curve for hospital beds.

There is evidence that the use of non-pharmacological interventions also limits the total number of infections. American cities that adopted these interventions more widely during the great flu of 1918 delayed the peak of infections, had lower peak mortality and lower total mortality (Markel et. Al, 2007).

In the current pandemic, all Brazilian states have restricted the movement of people to some degree. There are costs and benefits to these measures, which means that the degree of political conflict over them reflects, directly or indirectly, the groups that are benefited and harmed by them.

Based on projections of lethality and the statistical value of life, it is estimated that the benefits of social distance in Brazil reach between R $ 350 billion and R $ 640 billion per month, 58% to 106% of the Brazilian Gross Domestic Product, respectively (Cardoso and Dahis, 2020). The statistical value of life calculates the value attributed by individuals to reduce the risk of lethality based on preferences, such as choosing less risky professions.

There are also costs imposed by the implementation of non-pharmacological interventions and by the risk aversion of individuals, who naturally decide to stay at home. The closure of economic activity means a loss of wages and production - and also of revenue at the various levels of government. In a rough account, a month without economic activity would mean a drop in 1/12 of production or 8.3%, which almost coincides with the drop in Chinese GDP in the first quarter of 2020, 6.8%.

This article seeks to build vulnerability indices of Brazilian states to Covid-19, considering as variables the Human Development Index, Current State Net Revenue per capita, Total health expenditure by the state and its municipalities per capita, Percentage of the

population with more than 65 years old, Percentage of households with more than six inhabitants, Percentage of households with access to the general network or cesspool connected to the network, Total population of the State, Number of deaths per COVID per 100 thousand inhabitants, Number of tests per thousand inhabitants, Division between total deaths and confirmed cases for purposes of measuring underreporting, Number of doctors per 100 thousand inhabitants, Number of confirmed cases per capita, Percentage of the population obeying quarantine and, finally, Number of respirators per 100 thousand inhabitants.

Our results contribute to the literature by bringing empirical evidence of the vulnerability of Brazilian states to the pandemic and to public policy makers in supporting decision making regarding the better allocation of human and hospital resources. The second section details the method used in the work and the database, section 3 presents the results and section 4 concludes.

2. METHODOLOGY

Using as a basis the methodology applied by the Institute of Applied Economic Research in the elaboration of its Atlas of Social Vulnerability in Brazilian Municipalities in 2015[1] (IPEA, 2015), ten available and reliable indicators were chosen at the state level. There are seven from the economic axis and three from the medical infrastructure axis.

They are assigned uniform weights for preparing the vulnerability map. Then, an index is constructed which is a weighted average of each of the indicators:

$$i_e = \tilde{\omega}_q \tilde{q}_e, \qquad \tilde{\omega}_q = \frac{1}{Q} \qquad (1)$$

where ω_q is the weight assigned to the indicator q, $\tilde{q}_e$ is the normalized index of the indicator q referring to the state e; and i_e is the composite index for the state e.

The index component indicators are Fiscal / Social Axis - State HDI; State Current Net Revenue per capita; State Health expenses per capita; Percentage of households with more than six people per household; Percentage of the population over 65 years; Access to sewage collection; and, Total population - and Health Infrastructure Axis - ICUs per 100,000 inhabitants; Doctors for every 100,000 inhabitants; and, Respirators per 100,000 inhabitants.

The Human Development Index variable was collected in the 2017 UNDP, the State Current Net Revenue per capita, Total health expenditure by the state and its municipalities per capita and Total State population variables were collected from SICONFI 2018. The values referring to the Percentage of the population over 65 years old, Percentage of households with more than six inhabitants and Percentage of households with access to the general network or cesspool connected to the network are contained in the 2018 PNAD, while Number of deaths by COVID per 100 thousand inhabitants, Quantity of tests per thousand inhabitants, Division between total deaths and confirmed cases for the purpose of measuring underreporting, Number of confirmed cases per capita and Number of respirators per 100 thousand inhabitants were obtained from the Ministry of Health on June 16, 2020. The Number of Doctors per 100

[1] IPEA (2015). *Atlas of Social Vulnerability in Brazilian Municipalities.* Available in site of IPEA.

thousand inhabitants was obtained from the report of the Association of Brazilian Doctors of 2018 and Percent population following the quarantine with the InLoco survey of May 31, 2020.

States were ranked according to these indicators, and weights and scores were defined. A standardized version of each indicator is used, by calculating the z-score[2]. For each component, the way to interpret this indicator is that a value of +1 means the state and is 1 standard deviation above the average.

The aggregate index resulting from this exercise is a relative classification of states: an aggregation of deviations from the underlying indicators around the national average. In this way, we have a comparative aspect of which States are in the least uncomfortable situation in the face of the pandemic and which are in need of greater attention from Governors and the Federal Government.

Motivation for choosing indicators

Ranking of states by HDI: The higher the state's human development index, the higher the average income of the population, the greater the access to formal education and the better the life expectancy of the population.

Current Net Revenue / Per Capita: As much of the effort to combat COVID-19 is concentrated in the States of the Federation, it is important to measure the fiscal capacity that each State has. However, the raw data tells us little. It is necessary to know the value per inhabitant (per capita) to understand the real effectiveness of the index. States with more revenue per capita can count on more effective policies than states with less fiscal power.

Per Capita Health Expenditure: Current Net Revenue gives us a more quantitative view of expenditure, but Health Expenditure (function 10) per State Capita can give us a more qualitative view of this expenditure. Both the expenditure of the States and that of all the municipalities of the respective State were added.

Percentage of households with more than six people per household: Housing density is presumably related to the spreading power of the disease and inversely related to the effectiveness of isolation measures.

Percentage of the population over 65 years: The main risk group for COVID-19 is the elderly population. Therefore, it is important to measure the percentage of people over 65 in the state population.

Access to sewage collection: The lack of access to sewage and inadequate sanitation conditions contribute to the decrease of families' immunity. Proper sewage disposal is essential for the protection of public health.

Total state population: Everything more constant, more populous states need more attention than less populous states.

ICU / per capita: ICUs are, at the moment, the main responsible for the survival or death of people infected (Moreira, 2020). The more ICUs per inhabitant in a state, the greater its capacity to face the pandemic.

[2] The z-escore it is the standardization of the indicators as deviations around the average of the indicators. Specifically, if q_i is an observer value for the indicator q in state i, the value normalized by z-score is $\tilde{q}_e = \frac{(q_e - \bar{q})}{dp(q)}$, where $\bar{q}$ is the average of the indicator q and $dp(q)$ is your standard deviation.

Doctors for every 100,000 inhabitants: In a pandemic, doctors are primarily responsible for treating the infected. Ideally, it would be important to have per capita data from specialized professionals such as intensivists or respiratory physiotherapists. However, the availability of this data is much more limited and less reliable. Therefore, it is assumed here that there is a strong correlation between the total number of doctors and other health professionals.

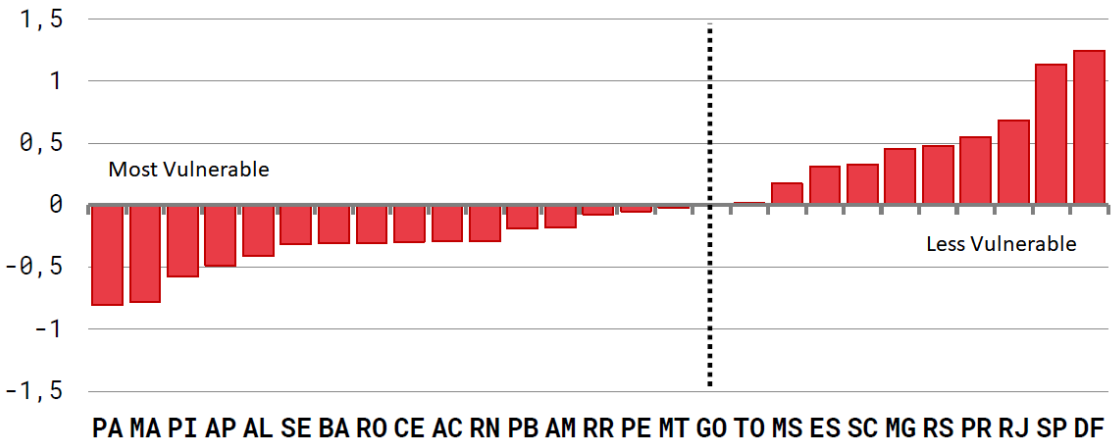
Respirators per 100,000 inhabitants: Respirators are the main equipment for treating patients with COVID19. States with more respirators tend to have greater power to respond to the spread of contagion.

3. RESULTS

The Figures 1 and 2 below report the composite index of vulnerability of States in combating Covid-19. As described above, the Covid-19 vulnerability index aggregates socio-fiscal and hospital indicators that are related to fighting the epidemic.

The indices have been normalized so that above-average states have positive indices and below-average states have negative indices. The unit of the index is weighted standard deviations.

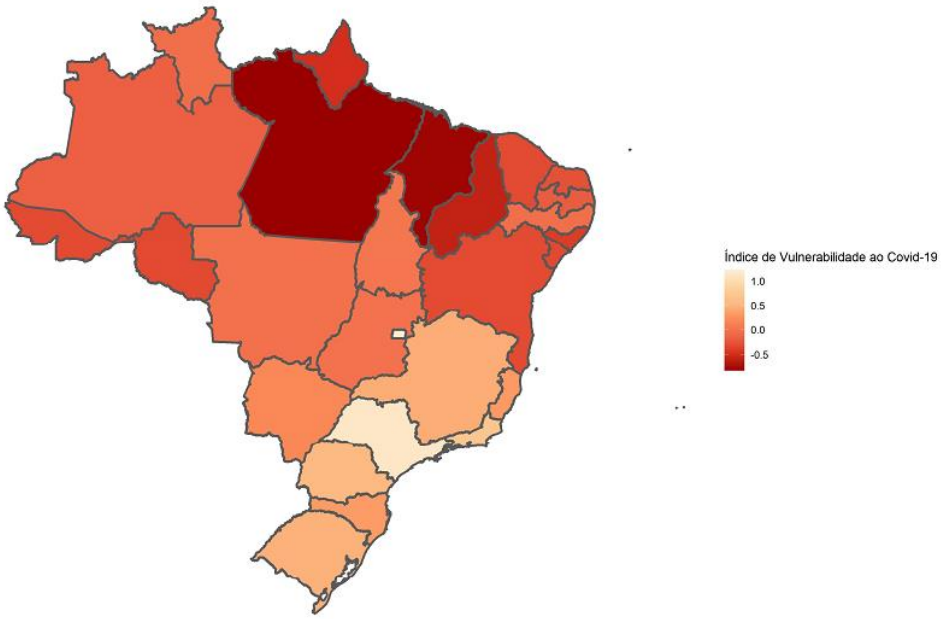
Figure 1. Brazilian States: Covid-19 Vulnerability Index



Note: Positive = better, in standard deviations around the mean.

Source: Elaborated by the authors.

Figure 2. Covid-19 Vulnerability Index

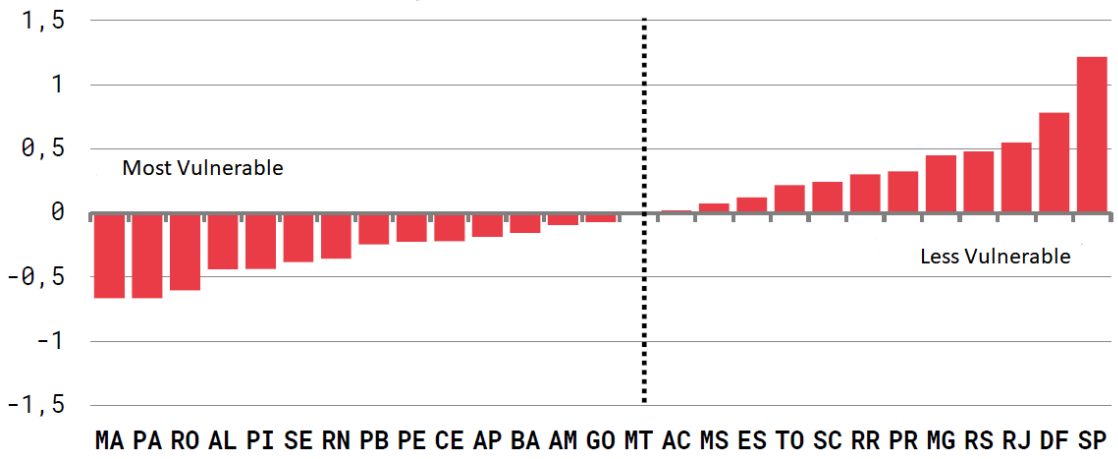


Note: Positive = better, in standard deviations around the mean.

Source: Elaborated by the authors.

In Figures 3 and 4, only the fiscal health and social development indicators of the States are considered. In them, it is possible to observe the trends of structural vulnerability indicators in the implementation of public health policies. Socio-fiscal indicators try to approximate the capacity of state governments to respond to shocks external to the health system.

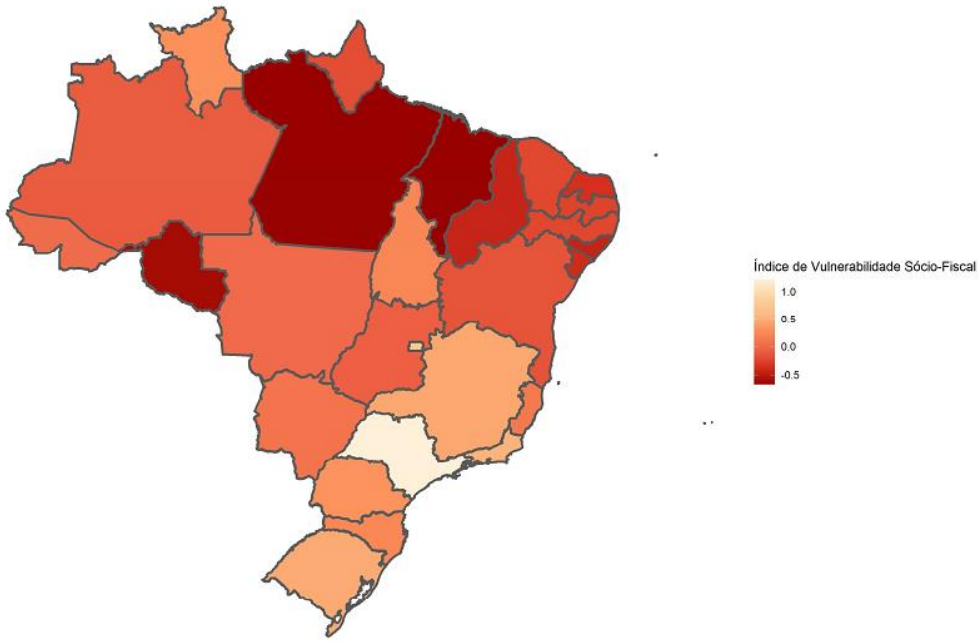
Figure 3. Brazilian States: Fiscal Social Vulnerability Index to Covid-19



Note: Positive = better, in standard deviations around the mean.

Source: Elaborated by the authors.

Figure 4. Social Fiscal Vulnerability Index to Covid-19

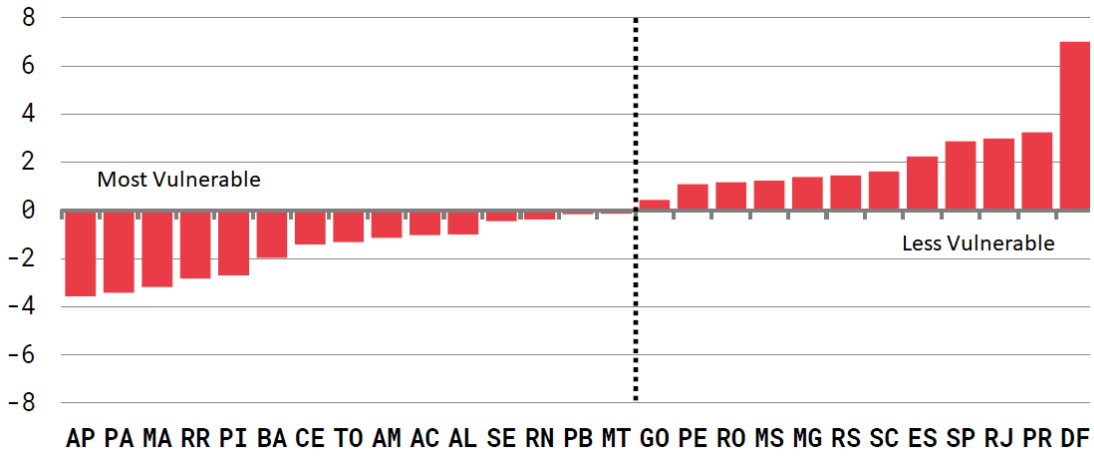


Note: Positive = better, in standard deviations around the mean.

Source: Elaborated by the authors.

Finally, the indicators of hospital vulnerability are shown below, which include the components of public ICU beds per inhabitant, the number of doctors per inhabitant and the number of respirators per inhabitant. It is expected that these indicators are more directly related to the intensity of the response to fight the epidemic, since they quantify the capacity stock of the public health system.

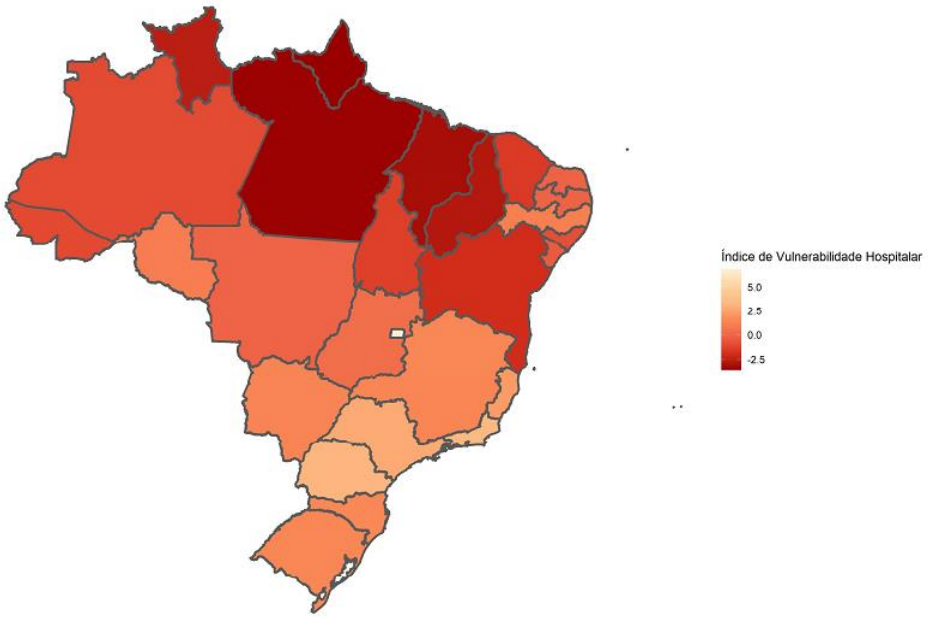
Figure 5. Brazilian States: Hospital Vulnerability Index to Covid-19



Note: Positive = better, in standard deviations around the mean.

Source: Elaborated by the authors.

Figure 6. Hospital Vulnerability Index to Covid-19



Note: Positive = better, in standard deviations around the mean.

Source: Elaborated by the authors.

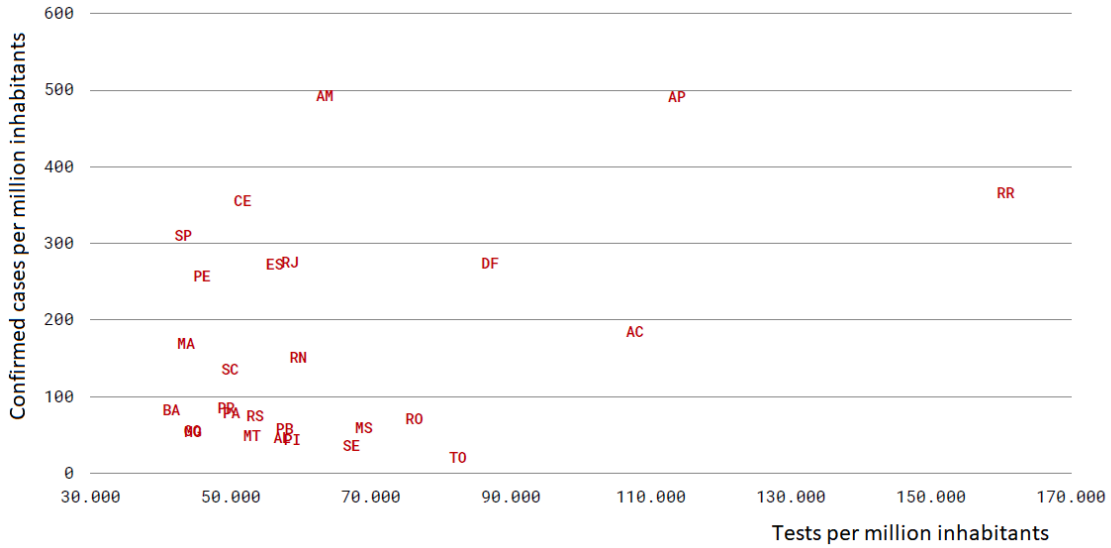
Case trends, mortality in different states and the relationship with vulnerability indexes

The comparison of the evolution of Covid-19 cases in Brazilian states suffers from several types of measurement errors that make the exercise complex. If such measurement errors were random and identical in different states, the comparison of data, although imperfect, would be simpler. Classification and measurement errors, however, are systematic and may differ between states.

The simplest measurement error is underreporting. If a given state provides more tests per capita than another with an identical number of real cases, all the more constant, the state with the most tests will have more cases reported.

There is a positive relationship between the number of tests per capita and the number of cases per capita between Brazilian states. Assuming that the effectiveness of tests is similar across states, this suggests that, for similar levels of testing, there are states with much higher levels of infection than others.

Figure 7. Brazilian States: tests and confirmed cases



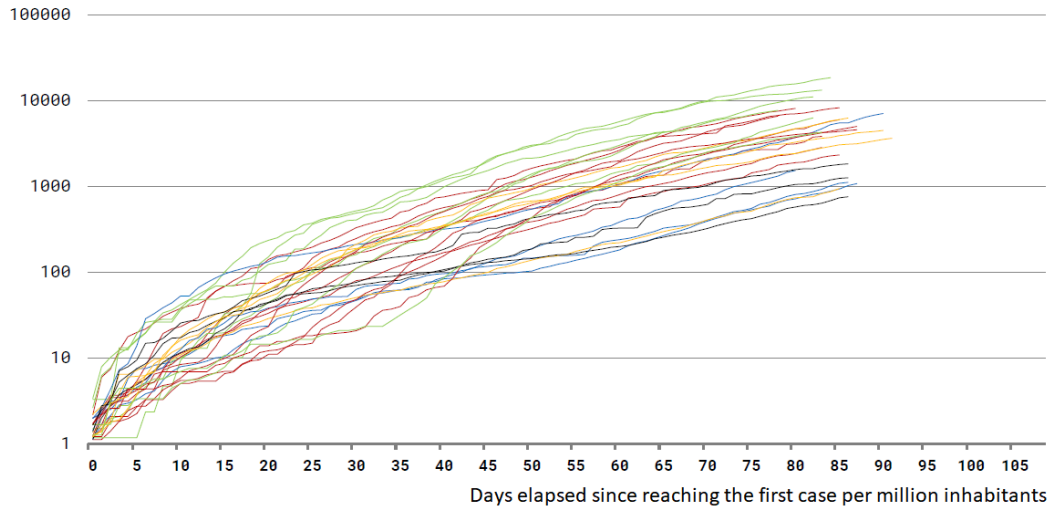
Note: In cases per million inhabitants and tests per million inhabitants on June 15, 2020.

Source: Elaborated by the authors.

The states of Amazonas, Ceará, Pará and Maranhão stand out in particular. Despite having similar levels of tests per capita to most Brazilian states, the number of reported cases is much higher.

When comparing the evolution of reported cases in different states, and considering the reservations made above, there is also a large dispersion in the number of reported cases. For the same number of days since the epidemic reached one case per million inhabitants, the number of cases reported in some states is up to ten times higher than others.

Figure 8. Brazilian States: cumulative cases of Covid-19



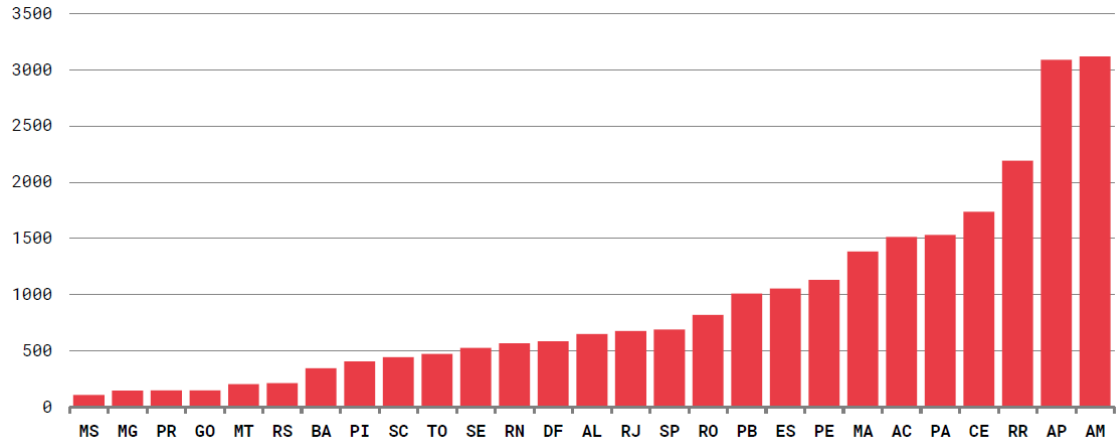
Note: In cases per million inhabitants, where yellow line represents north, red line represents northeast, orange line represents southeast, blue line represents center-west and black line represents south.

Source: Ministry of health of Brazil.

It stands out negatively in the analysis of the curve of infections notified to the North. For the same number of days that have passed since the epidemic reached one case per million inhabitants, the number of cases reported in states in the Northern region is more than ten times higher than in states with fewer infections.

This pattern becomes clearer when observing the transverse dimension for any fixed point in time. The graph below shows the number of cases per million inhabitants in the different states exactly 100 days after the number of cases reaches 1 case per million inhabitants.

Figure 9: Cumulative cases of Covid-19 per million inhabitants



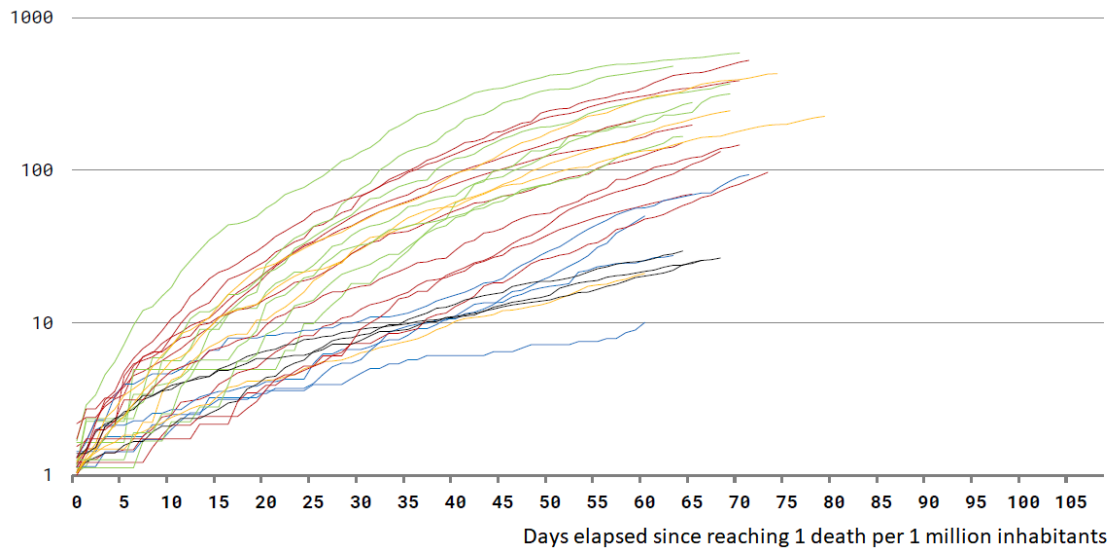
Note: Cases per million inhabitants 50 days after counting reaches 1 case per million for the state.

Source: Ministry of health of Brazil.

The problem of underreporting tends to be less in the number of deaths than in relation to the number of cases. This is because the cases of hospitalizations followed by deaths are monitored by health professionals who must assess the cause of death in order to issue a death certificate.

However, the comparison between the evolution of the number of deaths in states, as well as between the evolution in the number of cases, must be taken with some skepticism. It is possible that there are systematic differences in health policy in state public systems that change the percentage of deaths correctly classified as victims of the disease.

Figure 10. Brazilian states: deaths by Covid-19

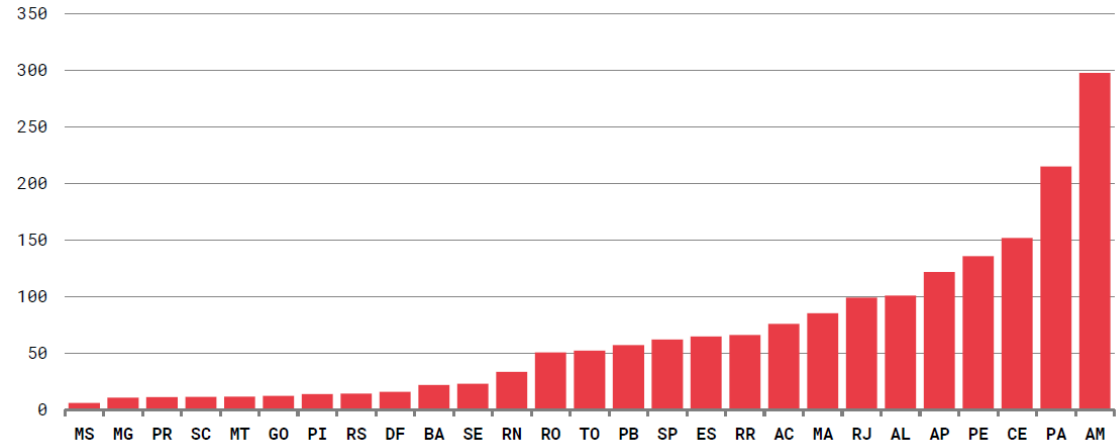


Note: In deaths per 1 million inhabitants, where yellow line represents north, red line represents northeast, orange line represents southeast, blue line represents center-west and black line represents south.

Source: Ministry of health of Brazil.

In the comparative analysis of the per capita mortality curve, the North and Southeast states and part of the Northeast states stand out negatively; and positively states in the Midwest and South. This conclusion is maintained even when using another methodology and calculating excess deaths (Fujiwara, 2020).

Figure 11. Brazilian States: Cumulative deaths of Covid-19 per million inhabitants

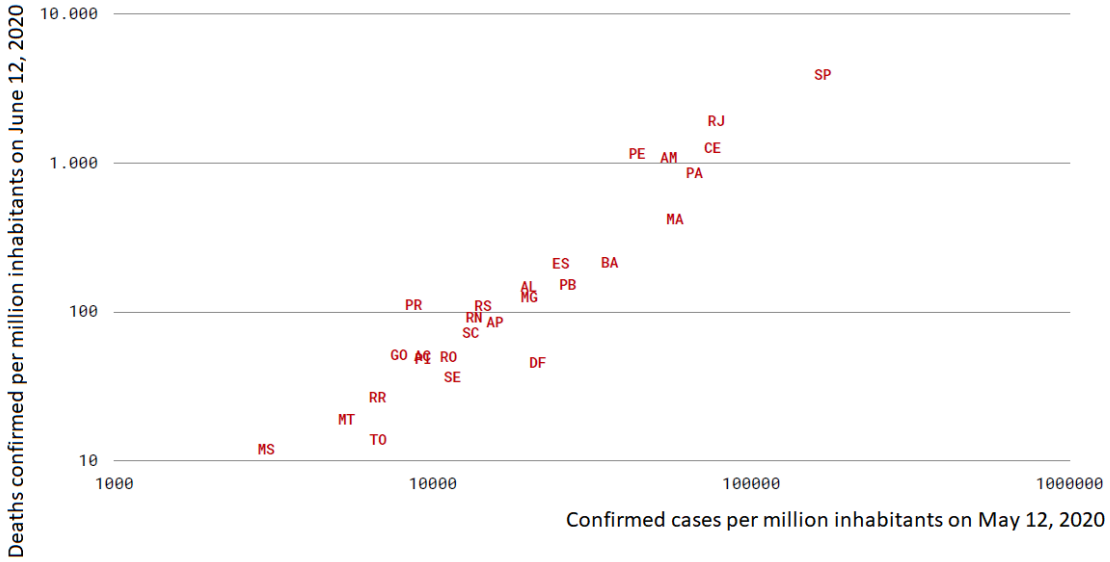


Note: Deaths per million inhabitants 50 days after counting reaches 1 case per million for the state.

Source: Ministry of health of Brazil.

The number of cases per capita a month earlier is a strong predictor of the number of deaths at a given point in time and the number of cases per capita a month earlier. Although this relationship is expected, given that a fraction of infected people tend to die, it is necessary to consider, however, that this correlation may be due to systematic measurement errors that affect both the notification of cases and the notification of deaths in the states.

Figure 12. Brazilian States: confirmed cases and deaths

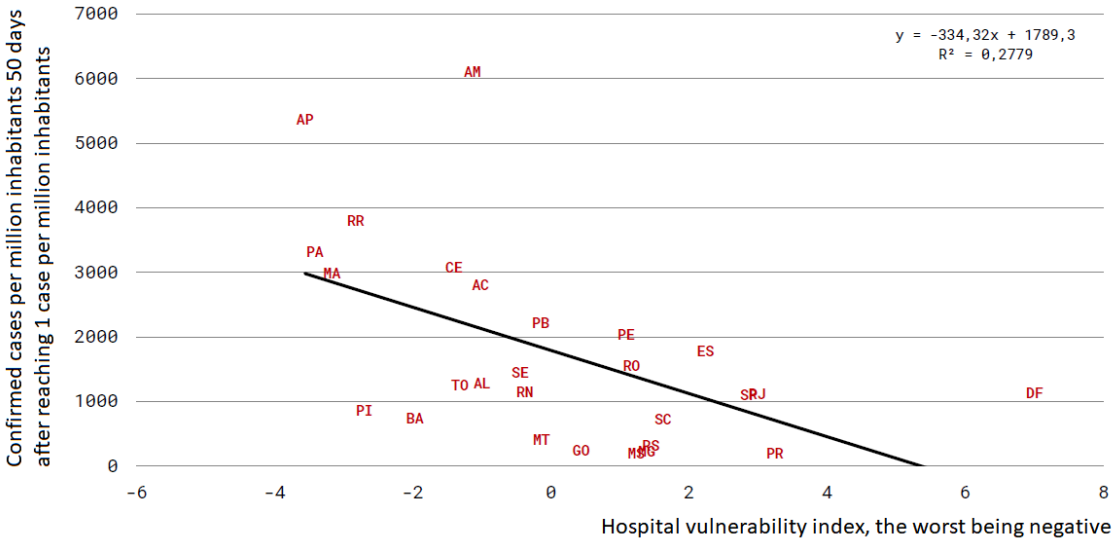


Note: In cases per million inhabitants on May 12, 2020 and confirmed deaths on June 12, 2020.

Source: Ministry of health of Brazil.

In the medium term, there is an association between the number of accumulated cases and the Hospital Vulnerability Index calculated in the previous section. Those states with the highest hospital vulnerability are those that observe the highest number of cases per capita.

Figure 13. Brazilian States: cases per million and hospital vulnerability

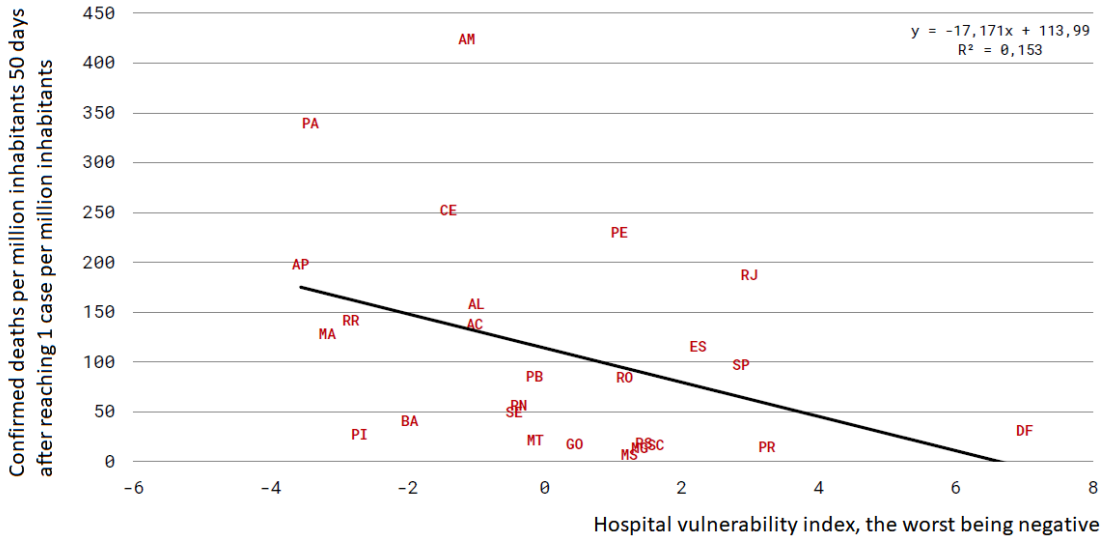


Note: In cases per 1 million inhabitants and standard deviations.

Source: Ministry of health of Brazil.

The same association exists, although at a lower level, between the Hospital Vulnerability Index and the number of deaths per capita. The reduction in association can result from several factors, such as missing variables that influence mortality at a higher level than infection (e.g. age structure). Another factor that can influence these divergences is the fact that, as illustrated by Figure 12, there is a lag in the association between the cumulative number of deaths and the cumulative number of cases.

Figure 14. Brazilian States: deaths per million and hospital vulnerability



Note: In deaths per 1 million inhabitants and standard deviations.

Source: Ministry of health of Brazil.

4. CONCLUSION

The Covid-19 pandemic is an unparalleled event in more than 100 years, with a potential for lethality ranging from hundreds of thousands to a few million. In this sense, it is up to the Brazilian State to make a considerable coordination effort to minimize both the number of deaths and the economic impact of the pandemic.

This work seeks to contribute to the debate through the elaboration of a state vulnerability index, comprising seven socio-fiscal indicators and three referring to the state hospital infrastructure. The hospital vulnerability index correlates with the number of cases so far. Given the impact of the number of cases today on the number of deaths in the medium term, the correlation between hospital vulnerability and state lethality is expected to become more evident over time.

The situation of the states of the North and Northeast in the indexes developed suggests that such regions should be viewed with special attention by public policies. Concerning to the states of the South and Center-West, the containment of the pandemic so far is combined with less vulnerability to Covid-19, indicating a privileged position of these states in relation to the rest of the federation.

The underreporting of cases and deaths presents itself as a serious obstacle both for the analysis in question and for the containment of the pandemic itself. This is undoubtedly a fundamental point on which the country needs to move forward in the fight against Covid-19.

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