FGV EBAPE

RAP
BRAZILIAN JOURNAL OF PUBLIC ADMINISTRATION

Socioeconomic vulnerability in the face of COVID-19 in municipalities of Ceará

Samuel Façanha Câmara [1]
Francisco Roberto Pinto [1]
Felipe Roberto da Silva [1]
Felipe Gerhard [1]

[1] Universidade Estadual do Ceará / Graduate Program in Administration, Fortaleza / CE – Brazil

The effects of the COVID-19 pandemic have caused serious socioeconomic impacts, exposing the vulnerability of Brazilian states and municipalities. In a broad sense, vulnerability is related to social and economic susceptibility to potential risks or losses caused by extreme events. In this context, this article identifies the municipalities' socioeconomic vulnerability in the State of Ceará, the epicenter of the COVID-19 pandemic in the Northeast of Brazil. This exploratory-quantitative study adopted secondary data from government databases of public access. The socioeconomic vulnerability of the municipalities was assessed dynamically, based on a mathematical model to forecast the number of cases of COVID-19 applied to the city of Wuhan, China. The vulnerability indicators were calculated under two trajectories: production value and the number of employed persons, considering municipal characteristics such as demographic density, local mobility, and human development index. In the case of the state of Ceará, the findings show a series of demographic, social and economic determinants that aggravate the impacts of the crisis. The vulnerability indicators constructed in this research can be used as a basis for decisions by municipal and state governments in the chronology of economic openings by sectors, municipalities, and regions.
Keywords: COVID-19; socioeconomic vulnerability; municipalities; Ceará.

Vulnerabilidade socioeconômica à COVID-19 em municípios do Ceará

Os efeitos da pandemia da COVID-19 têm causado sérios impactos socioeconômicos, expondo a vulnerabilidade de estados e municípios brasileiros. Concebendo-a em sentido amplo, a vulnerabilidade se relaciona à suscetibilidade social e econômica a riscos ou perdas potenciais, causados por eventos extremos. Nesse contexto, este artigo objetiva identificar a vulnerabilidade socioeconômica dos municípios do Ceará, epicentro da região Nordeste, quanto à pandemia da COVID-19. Para tal, realizou-se um estudo exploratório-quantitativo, utilizando-se informações secundárias obtidas em bases de dados públicas governamentais. A vulnerabilidade socioeconômica dos municípios foi avaliada de forma dinâmica, baseando-se em modelo matemático de previsão do número de casos da COVID-19 aplicado à cidade de Wuhan, na China. Os indicadores de vulnerabilidade foram calculados sob duas trajetórias: valor de produção e número de pessoal ocupado, considerando-se características municipais como densidade demográfica, mobilidade interurbana e índice de desenvolvimento humano (IDH). No caso do estado do Ceará, os achados evidenciaram uma série de determinantes demográficos, sociais e econômicos locais que agravam os impactos da crise. Os indicadores de vulnerabilidade construídos na pesquisa podem servir de base para as decisões de governos municipais e estadual na cronologia da abertura econômica do estado por setores, municípios e regiões.
Palavras-chave: COVID-19; vulnerabilidade socioeconômica; municípios; Ceará.

DOI: http://dx.doi.org/10.1590/0034-761220200133x
Article submitted on April 02, 2020 and accepted on July 07, 2020.
[Translated version] Note: All quotes in English translated by this article's translator.

ISSN: 1982-3134

Vulnerabilidad socioeconómica a la COVID-19 en municipios de Ceará

Los efectos de la pandemia de COVID-19 han causado graves impactos socioeconómicos, exponiendo la vulnerabilidad de los estados y municipios brasileños. Considerándola en un sentido amplio, la vulnerabilidad está relacionada con la susceptibilidad social y económica a los riesgos o pérdidas potenciales causados por eventos extremos. En este contexto, este artículo tiene como objetivo identificar la vulnerabilidad socioeconómica de los municipios de Ceará, el epicentro de la pandemia de COVID-19 en la región noreste. Para ello, se realizó un estudio exploratorio cuantitativo, utilizando información secundaria obtenida a través de bases de datos públicas del gobierno. La vulnerabilidad socioeconómica de los municipios se evaluó dinámicamente, con base en un modelo matemático de pronóstico del número de casos de COVID-19 aplicado a la ciudad de Wuhan, China. Los indicadores de vulnerabilidad se calcularon con base en dos trayectorias: valor de producción y número de personas empleadas, considerando características municipales como densidad demográfica, movilidad interurbana e índice de desarrollo humano. En el caso del estado de Ceará, los resultados mostraron una serie de determinantes demográficos, sociales y económicos locales que agravan los impactos de la crisis. Los indicadores de vulnerabilidad construidos en la encuesta pueden servir como base para las decisiones de los gobiernos municipales y estatal en la cronología de apertura económica del estado por sectores, municipios y regiones.

Palabras clave: COVID-19; vulnerabilidad socioeconómica; municipios; Ceará.

1. INTRODUCTION

Rittel and Webber (1973) developed the concept of 'wicked problems' to designate issues that require collective efforts and are considered uncertain, controversial, and difficult or impossible to solve. According to the literature, wicked problems are undetermined events marked by singularities. They do not have a single diagnosis, and the consequences of the solutions proposed to address them are irreversible. They do not follow a rational structure, are not subject to a conclusive solution, and, as these events comprise a subset of problems that interact simultaneously, causing a cascade effect, they cannot be analyzed out of context (Head & Alford, 2015).

Because of the numerous factors involved in an individual's health and well-being – such as the environment, life condition, genetics, and social and economic factors –, pathological outbreaks may be considered wicked problems (Kreuter, Rosa, Howze, & Baldwin, 2004). Pandemic viral outbreaks such as H1N1 and, more recently, COVID-19, are phenomena that affect not only health but also the global economy (Mclafferty, 2010).

The COVID-19 pandemic has generated a worldwide crisis that demands emergency strategies and collective action and has exposed biological, physical, and spatial vulnerabilities, as well as social and economic instability. The literature has numerous examples of studies tackling these aspects, such as the works by Rakauskiene and Strunz (2016), and Briguglio, Cordina, Farrugia, and Vella (2009), who focus on the social and economic dimensions. However, there is little research discussing the socio-economic fragility in the face of a wicked problem such as the COVID-19 pandemic or exploring the consequences of this fragility for the market and society.

This study focuses on the Brazilian state of Ceará, which is the state with the most confirmed cases of COVID-19 in the Northeast (401 people infected by March 31) (Secretaria de Saúde do Ceará [Sesa], 2020). In the face of the pandemic's development, the study seeks to answer the following research question: what is the socio-economic weakness of the municipalities of Ceará regarding the effects of the COVID-19 pandemic, considering Fortaleza – the state capital city – as the local epicenter? The objective of the study, therefore, was to identify the socio-economic insecurity regarding the demands posed by the COVID-19 pandemic in the states' municipalities.

2. SOCIOECONOMIC VULNERABILITY

Social and economic vulnerability is related to the material or moral susceptibility of certain social groups or society to potential risks or losses caused by extreme events (Hand, Eichman, Triepke, & Jaworski, 2018). Thus, threats such as the COVID-19 pandemic affect spatial dynamics, generating biological, political, economic, and social insecurities (Li et al., 2020; Jia, Li, Jiang, & Guo, 2020). Mclafferty (2010) explains that the presence of pathogens in a given location is a condition for virus transmission and the start of an outbreak. However, other factors decisively contribute to shaping disease development. Therefore, people are exposed differently according to the region, and their individual physical condition and level of access to treatment.

In Brazil, for example, the fight against COVID-19 in states involves the adoption of measures such as the self-isolation (quarantine) in the case of infected people or suspected cases, and measures to increase social distancing among the population, in order to reduce transmission. The seclusion of a large part of the population has brought direct consequences to the economy, affecting non-essential services such as bars, restaurants, cafeterias, places of worship, museums, cinemas, theaters and other points of tourism and leisure, shops in general, gyms, and industries (Decreto n. 33.519 de 19 de março de 2020, 2020).

The effects of the measures currently adopted throughout Brazil may be anticipated by observing examples from other regions that faced similar events in the past. Siu and Wong (2004) report the case of Hong Kong during the SARS pandemic of 2003, showing that, until mid-April of that year, Hong Kong alone witnessed the temporary closure of at least 50 restaurants, and sales in this sector fell by 20%. The pandemic severely affected other areas such as tourism and the airline industry. Tourism saw a 10.4% drop in the number of visitors, and airlines had an estimated loss of USD 3 million a day, given that flight cancellations across the region rose from 10% in late March to 40% in mid-April (Siu & Wong, 2004).

As observed above, pandemics present all characteristics of wicked problems and must be faced accordingly. It is crucial to minimize their effects by adopting strategic emergency plans that consider perspectives other than rational systems since wicked problems rarely accept a single solution. Also, it is important to keep in mind that a solution offered to this kind of problem will imply a new comprehension about the issue, requiring the constant creation and adoption of new measures (Head & Alford, 2015; Rittel & Webber, 1973).

3. METHODOLOGY

This quantitative research is characterized as an exploratory study using secondary data. The research calculated the indices 'broad socio-economic vulnerability' (BV), 'territorial vulnerability' (TV), and 'dynamic vulnerability' (DV). The results were associated with the projected growth rate of the number of people infected with the new coronavirus in the 184 municipalities in the state of Ceará, with Fortaleza – the capital city – as the epicenter.

Secondary data was collected from the following public government databases:

1) *Relação Annual de Informações Sociais* (Rais) (annual list of social information), which offers the classification of economic sectors grouped into classes established by the National Classification of Economic Activities (CNAE) 2.0;
2) Data on the state's tourist mobility, obtained from the Ministry of Tourism (MTUR, 2020)
3) Sociodemographic data from the municipalities of Ceará, collected from the Brazilian Institute of Geography and Statistics (IBGE).

The analysis of the state's economic activities used data extracted by classes of sectors, representing a separation of the classes described in the CNAE into five levels. It was, therefore, possible to analyze the structure of the local economy in detail (IBGE, 2020b). In a universe of 673 classes available in the national classification, the state economy comprises 610, including economic activities in the primary, secondary, and tertiary sectors.

As for tourist mobility, the research used data from the Ministry of Tourism (2020). The Ministry defines and classifies the priority tourist areas in the country, categorizing them from A to E, according to the performance of the municipalities' economy in the sector, estimating their international and domestic demand. These concepts allow analyzing the intermunicipal flow of people, and identifying the locations with greater urban mobility, a factor directly related to susceptibility to infectious outbreaks (Lins-de-Barros, 2017).

The analysis occurred in three stages, and the calculation took two paths: a) collecting the number of employed persons and b) estimating the value of production, i.e., the value of each sector's participation in the GDP (based on the number of jobs generated and the average wages, per sector). The broad vulnerability (BV) was calculated in the first stage, using Equation 1 adapted from Nelson and Grubesic (2018):

$$BV = \sum_{i=1}^{n} (NE \,.\, E_j) \qquad \text{(Equation 1)}$$

V = Number of formally employed persons (NE), or estimation of the value of the sector's participation in the municipality's GDP in the year analyzed;
E_j = Vulnerability of the j-nth indices of class of the respective municipality (varying from 0.1 to 1).

To calculate the E_j, three categories were evaluated for each class of economic activity. The first was the class' 'position in the supply chain,' assigning a score from 1 to 4, according to the impact suffered by each class based on the state government Decree 33519, of 2020. The second category was the 'potential of human contact,' assessing the sectors with activities more likely to facilitate virus transmission. In this category, the scores ranged from 0 to 3, considering the size of the companies, the possibility of working from home, and the professionals' direct contact with customers or other employees. The third category assessed the level of internationalization of each class, analyzing the sectors most dependent on exports or imports (scores also varied from 0 to 3). Finally, the scores were added, divided by 10 (ranging from 0.1 to 1), and multiplied by the number of employed persons or the value of production (participation of the sector in the GDP of each municipality).

The second stage included the municipal characteristics, measuring the territorial vulnerability index (TVI_m). The first variable analyzed was the demographic density (D), obtained from IBGE (2020a) and separated into quartiles from the lowest to the highest concentration of people. The second variable assessed was the tourist mobility (M), obtained from the Ministry of Tourism (2020), following the same procedure adopted for the first variable. Finally, for the indicator of the municipalities' social development (ID) we used the human development index (HDI), also extracted from IBGE (2020a). The quartile calculation considered an inversely proportional relationship since lower HDI indexes indicated higher quartiles. We determined in which quartile the municipality was, for each variable, and the following values were obtained (D, M, and ID): Q1 (0.0825), Q2 (0.165), Q3 (0.2475), Q4 (0.333). Thus:

$$TVI = NE \,.\, (D + M + ID) \qquad \text{(Equation 2)}$$

TVI = Vulnerability per employed persons (number of employed persons – NE) or vulnerability per GDP (in Brazilian Real) in the respective municipality;
D = Municipality's demographic density (pop./km^2);
M = Municipality's tourist mobility (number of travelers);
ID = Indicator of development of the municipality (HDI, ranging from 0 to 1).

The third stage of the research was to associate vulnerability indicators with the dynamics of confirmed cases of COVID-19 in municipalities in the state of Ceará, estimating the period of the infection's duration. We adopted a mathematical model based on the growth representation of Gompertz (1825), created originally to assess the extinction of populations. Jia et al. (2020) used the same model to predict the number of cases in the city of Wuhan – the epicenter of the outbreak in China – and understand the factors that influence the virus transmission. The equation used in the third stage was:

$$Q_t = ae^{-be - c(t-t_0)} \qquad \text{(Equation 3)}$$

Q_t = Cumulative confirmed cases (number of cases);
a = Maximum number of confirmed cases predicted;
b and c = Adjustment coefficients;
t = Days since the first case;
t_0 = Day of the first case.

The parameters of the equation for the municipalities of Ceará were estimated based on the coefficients applied in Wuhan. The 'Excel solver' tool was used to optimize the parameters of equation 3. The aim was to sum the squared differences of the cases estimated and the real cases in the capital city, Fortaleza. We adopted, initially, the estimates made by Jia et al. (2020) for the region of Wuhan, except the maximum number of confirmed cases predicted. At the time of the estimate, there were no parameters on the maximum number of cases reported in the cities of Ceará, which led to minimized estimates for this ceiling. This choice did not jeopardize the research since the intention was to assess the acceleration and the average speed of transmission in the different phases, rather than the exact number of cases.

Another issue corroborating the initial estimate considering a ceiling for the number of cases was the less pessimistic scenario observed for the dynamics estimated, which should disfavor social distancing policies. However, the results obtained from such policies are desirable. Thus, the result was a curve, in an optimistic scenario, adjusted to the accumulated cases of Fortaleza as the epicenter of the real cases in Ceará. This curve was divided into three phases:

1) The accelerated initial growth (phase 1), in which the curve grows at an accelerated rate:
$dQ_t/dt > 0$ and $d^2Q_t/dt^2 > 0$

2) The resistant slowdown growth (phase 2), which includes accumulated cases that grow at a slow rate and with an increasing average speed:
$dQ_t/dt > 0$ and $d^2Q_t/dt^2 < 0$ and $d(Q_t/t)/dt > 0$

3) The residual (phase 3), with increasing accumulated cases, but with decreasing average speed:
$dQ_t/dt > 0$ and $d^2Q_t/dt^2 < 0$ and $d(Q_t/t)/dt < 0$

$$Q_t/t = \text{average speed of cases.}$$

When associating these phases to the vulnerability indicators, adjusting them to the dynamics of the case curve for the time in days of each phase, it was possible to find an accelerated increasing vulnerability (DV_a) in the first phase, which is measured as a function of TVI (Equation 2):

$$DV_a = \frac{TVI}{360} \cdot t_a \qquad \text{(Equation 4)}$$

DV_a = Increasing accelerated vulnerability, and increasing speed per employed persons or per GDP (in Brazilian Real) in the municipality;
TVI = Territory vulnerability index in the municipality during the accelerated initial growth (phase 1), for formally employed persons or GDP (in Brazilian Real);
t_a = Period in days of phase 1.

In the second phase, the number of cases grows at a slower pace, but the impact on the economy is greater because the economic agents' perception of the cumulative effect is not dissipated. The vulnerability, therefore, tends to increase. We calculated the difference between the two phases using a corrector from the second to the first phase, depending on the speed with which these cases occur in comparison with each other. Thus, in the second phase, the TVIs were calculated based on the following equation:

$$DV_d = TVI \cdot \frac{I_c}{360} \cdot t_d \qquad \text{(Equation 5)}$$

DV_d = Increasing accelerated vulnerability, and decreasing speed – designated as resistant slowdown growth per formally employed persons or per GDP (in Brazilian Real) in the municipality;
TVI = Territory vulnerability index per formally employed persons, or per GDP (in Brazilian Real) in the municipality;
I_c = Corrector depending on the speed of the coronavirus cases during the two first phases;
t_d = Tempo em dias da fase 2.
t_d = Period in days of phase 2.

The calculation of I_C considers the relationship between the speed of the first and the second phases:

$$I_c = \frac{Q_t/t\ (phase\ 2)}{Q_t/t\ (phase\ 1)} \qquad \text{(Equation 6)}$$

In the third phase (residual vulnerability), there is a deceleration of the cases and the speed of transmission. The assumption is that the impact on economic activity becomes residual, once the region reaches the maximum number of infected people. The impacts in this phase can extend over time in unpredictable ways, and the outcomes depend on the economy's ability to recover as well as on other unforeseen events. Thus, in the third phase, the TVIs were calculated based on three scenarios, ranging from the tipping point that marks the end of the second phase to 120th day (scenario 1), from 121st to 180th day (scenario 2) and from 181st to 360th day (scenario 3). For each scenario, both the value of production and the number of employed persons were used as parameters, following the equation:

$$RV = TVI \cdot \frac{I_R}{360} \cdot t_{Ri} \qquad \text{(Equation 7)}$$

TVI = Territory vulnerability index per formally employed persons, or per GDP (in Brazilian Real) in the municipality
I_R = Corrector depending on the speed of the coronavirus cases between the first and the last phases;
t_{Ri} = Period in days of phase3 for the i-nth scenarios of different periods of recovery.

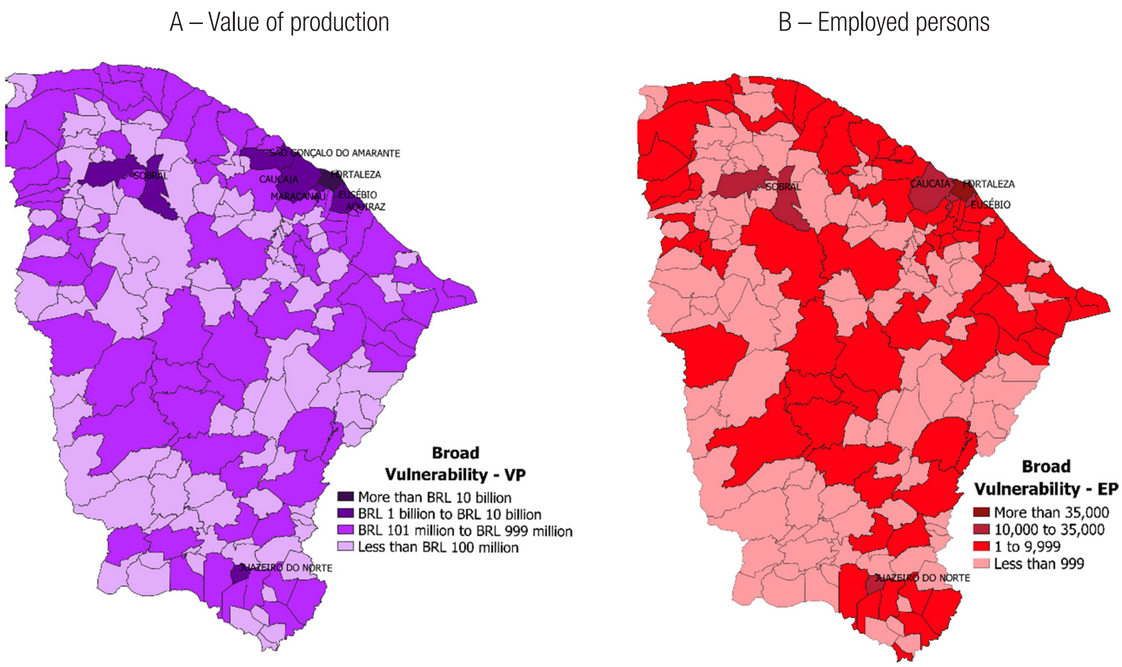
The calculation of I_R considers the relationship between the speed of the first and second phases:

$$I_R = \frac{Q_t/t\ (phase\ 3)}{Q_t/t\ (phase\ 1)} \qquad \text{(Equation 8)}$$

4. ANALYSIS OF BROAD VULNERABILITY

Broad vulnerability (BV) prioritized economic aspects, as observed in Figure 1.

FIGURE 1 INDICES OF BV PER MUNICIPALITY



Source: Elaborated by the authors using Qgis 3.4

The maps show that the municipality with the highest vulnerability index regarding the formally employed persons is Fortaleza, with 396,000 vulnerable people (52.2% of the total in the state), followed by the municipalities of Juazeiro do Norte and Maracanaú, with around 33,000 (4.3%) and 32,000 (4.2%), respectively. The capital city significantly influences the results, as it comprises more than 768,000 formal employment relationships, or 52.2% of the employed persons in Ceará (Rais, 2018).

Juazeiro do Norte has more than 49,000 formal jobs. Despite having 14.3% less formally employed persons than Maracanaú, Juazeiro do Norte is in the second position among the most vulnerable municipalities presenting 15,904 formal jobs in the tertiary sector, more precisely in the trade and services sectors. Added to the total number of employed persons in the two regions, there are potentially 30,451 layoffs that could be generated in these sectors because of the pandemic, in areas of extreme socio-economic vulnerability.

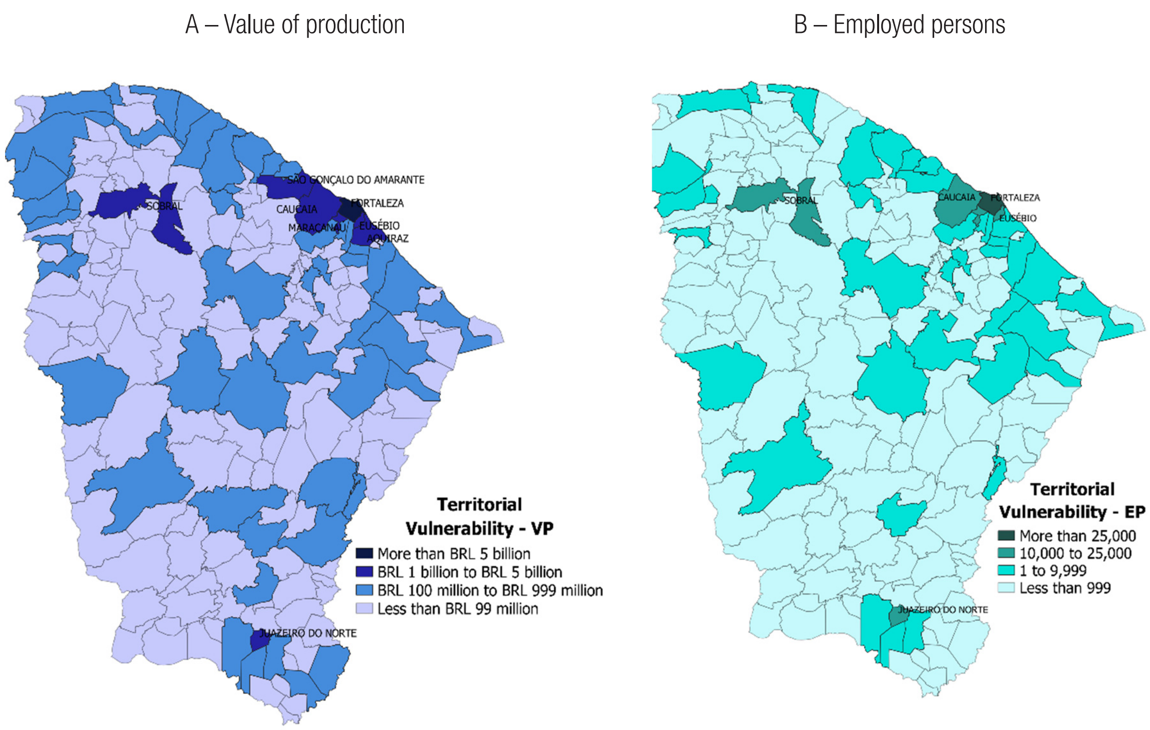
The second parameter to analyze the BV considered the estimate of the sector's participation in the municipality's GDP. Similarly to the case of the employed persons, Fortaleza is the most vulnerable region, with an index above R$ 37 billion, that is, almost the seventh and tenth of the second (Maracanaú) and third (Caucaia) places. In the capital city, the sum of the average wage in commerce and service activities corresponds to about BRL 332 million, or 16.3% of the total wages in the city. Previous studies (Siu & Wong, 2004; Mckercher, 2003) show that viral outbreaks severely affect these sectors, particularly the businesses related to tourism and hospitality due to the fear of large-scale transmission, insecurity, and social distancing measures. In Brazil, the number of establishments in this segment (hotels, resorts, flats, and hostels), grew from around 10,700 in the third semester of 2018 to approximately 14,000 in the same period of 2019, an increase of 19.5% only in Ceará (Sistema de Cadastro de Pessoas Físicas e Jurídicas que Atuam no Setor do Turismo [*Cadastur*], 2019).

In comparison to the first parameter to analyze BV, in the sector's participation in the municipality GDP, the municipality of Maracanaú gained one position, with a vulnerability index close to BRL 5.5 billion (6.3%), followed by Caucaia (BRL 3.6 billion, or 4.2%). Juazeiro do Norte, which was the second most vulnerable in the parameter regarding employment, appeared here among the five most vulnerable municipalities in the state, with an index of approximately BRL 3 billion.

4.1. Analysis of territorial vulnerability

In addition to the sectoral aspects of each economic activity, some variables are essential to measure the socio-economic vulnerability of a given community or territory. The results of the TV measurement can be seen in Figure 2.

FIGURE 2 INDICES OF TV PER MUNICIPALITY



Source: Elaborated by the authors using Qgis 3.4

We considered the value of production and the number of employed persons again to calculate TV. For the value of production, the most vulnerable municipalities were Fortaleza, with an index of BRL 27.9 billion (47.1% of the state total), followed by Maracanaú (BRL 3.2 billion), Caucaia (BRL 2.4 billion), Juazeiro do Norte (BRL 2.2 billion) and Sobral (BRL 2.1 billion). The indices of these municipalities, together, represent about one third of the vulnerability observed in the capital city.

When the parameter is the number of employed persons, the ranking of municipalities is similar to that found for BV. Fortaleza leads with an index of 296,864 formally employed persons, followed by Juazeiro do Norte (24,700), Maracanaú (18,500), Sobral (18,300), and Caucaia (15,600). As for territorial characteristics, these municipalities are among the ten with the highest HDI, tourist mobility, and demographic density of the state. Although these indicators are opposite in the calculation of municipal BV, the high HDI was not sufficient to reduce the strong effects of tourist mobility and demographic density on the vulnerability of municipalities.

Table 1 classifies the municipalities in the state by mesoregions, indicating the total value of production and employed persons in these areas in the respective vulnerability indices.

TABLE 1 TOTAL VALUE OF PRODUCTION AND EMPLOYED PERSONS PER MESOREGION

Mesoregion	BV – GDP	TV – GDP	BV – EP	TV – EP
Northwest Ceará	8,504,949,874.79	6,023,683,168.83	69,629	49,476.64
North Ceará	5,587,181,761.02	4,036,853,559.25	38,939	28,091.69
Metropolitan Area of Fortaleza	45,973,015,666.37	33,779,648,483.16	455,034	336,380.17
Sertões Ceará	8,705,831,804.19	4,897,179,771.22	58,082	32,252.49
Jaguaribe	6,525,709,192.14	3,846,025,844.95	49,806	29,667.55
Center-south Ceará	2,053,787,915.06	1,308,355,237.63	16,524	10,332.06
South Ceará	7,316,606,328.06	4,799,807,276.98	69,778	46,642.11
TOTAL	84,667,082,541.63	58,691,553,342.02	757,792	532,842.71

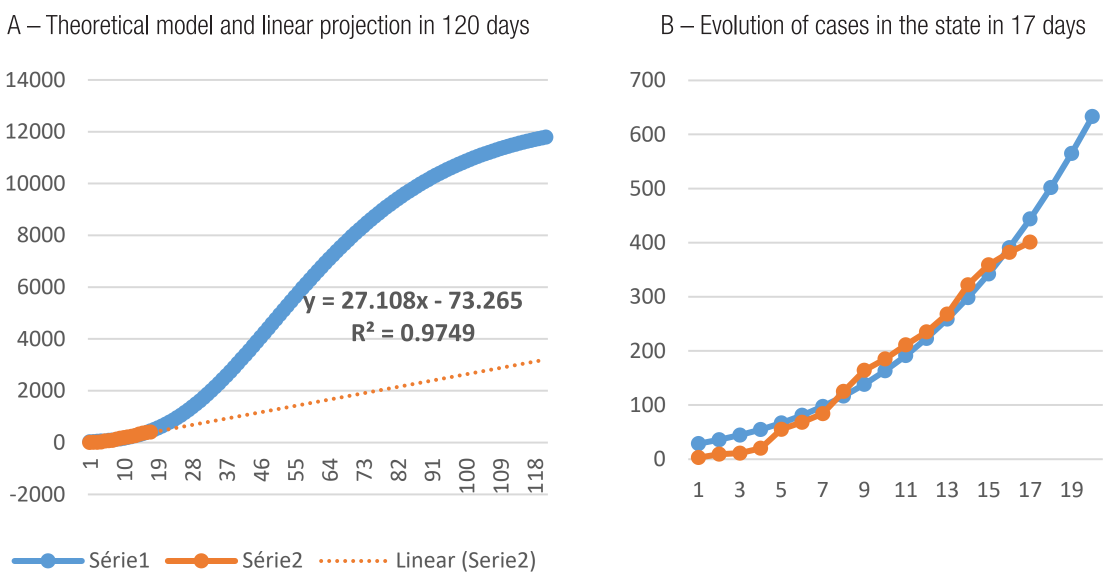
Source: Elaborated by the authors.

The table reveals that the mesoregion with the highest vulnerability indexes was the Metropolitan Area of Fortaleza, which brings together a smaller number of municipalities in comparison to other mesoregions (Fortaleza, Caucaia, Aquiraz, Maranguape, Horizonte, Pacajus, Pacatuba, Itapajé, and Itaitinga), five of which are among the twenty most vulnerable municipalities in the state. Considering only TV, there is a potential loss of BRL 33.7 billion in value of production and 336,000 formally employed persons that are at risk of dismissal as these municipalities are at the beginning of the vulnerability line.

4.2. Analysis of dynamic vulnerability and social distancing

For the analysis of the dynamic vulnerability, the first phase (accelerated initial growth) was projected from March 15 to April 28, while the second (resistant slowdown growth) was projected from April 29 to May 21. For the third (residual), three scenarios were considered: starting on May 22 until reaching the 120th day (scenario 1); from the 121st day from the beginning of the residual phase until the 180th day (scenario 2); and from the 181st day from the beginning of the residual phase until the 360th day (scenario 3). Thus, since Fortaleza is the epicenter of the pandemic in the state, its curve of accumulated cases was stipulated as the dynamic of economic influence for the other municipalities. Graph 1 shows the mathematical model of Gompertz adjusted to the real confirmed cases of infection in Ceará. A trend line was estimated, based on the confirmed cases, by linear regression, as a way to simulate the effect of social distancing measures taken by the state government on confirmed cases of COVID-19.

GRAPH 1 GOMPETZ CURVE ADJUSTED TO REAL CASES AND PROJECTION OF THE TENDENCY LINE, REPRESENTING FUTURE CASES CONSIDERING THE EFFECT OF SOCIAL DISTANCING MEASURES



Key: Series 1 – Wuhan curve; Series 2 – Ceará curve; Linear – Linear projection for cases in the state; Blue series – Gompetz curve (adjusted); Red series – Confirmed cases; Dashed series – Linear trend considering social distancing measures.
Source: Research data (2020).

When analyzing the adjusted theoretical curve, the study identified the day correctors for each phase. We adjusted the linear trend based on the behavior of confirmed cases for the scenario considering the social distancing measures adopted. Table 2 shows the findings regarding DV, referring to GDP and employed persons.

TABLE 2 TOTAL VULNERABILITY INDEX FOR CEARÁ PER PHASES OF THE CASES DYNAMIC (WITHOUT SOCIAL DISTANCING)

Vulnerability	Dynamic without social distancing				
	1st phase (initial)	2nd phase (resistant)	3rd phase (residual)		
			120th day	180th day	360th day
Territorial – GDP	5,217,026,964	21,194,172,040	17,803,104,514	11,477,459,320	10,189,505,789
Territorial – EP	47,364	192,415	161,629	104,200	92,507

Source: Research data (2020).

The second (resistant) phase of the pandemic curve showed the highest absolute value of vulnerability, around BRL 21.2 billion and 192.4 thousand formally employed persons. This value is progressively reduced over the three periods of the third (residual) phase, because of the percentage decrease in the number of cases among periods. As the number of cases is a determining factor for calculating the vulnerability of each phase, it is observed that even shorter periods presented higher vulnerability indices, as is the case of the scenario between days 120 and 180 of the residual phase (GDP: BRL 11.5 billion; employed persons: 104.2 thousand).

Table 3 shows the DV, demonstrating the difference in percentage between the scenarios with and without social distancing (i.e., with the Gompetz curve evolving freely). The phases of the Gompetz curve were not considered because the behavior of the estimated curve (with social distancing) is linear, and the average speed of the cases is practically constant, which generated a corrector for all periods, which is related to the speed of the confirmed cases.

TABLE 3 TOTAL VULNERABILITY OF PHASES CONSIDERING DAYS 120, 180, AND 360, FOR THE STATE OF CEARÁ (WITH SOCIAL DISTANCING)

Vulnerability	120th day	180th day	360th day
Territorial – GDP	5,086,601,290	2,543,300,644	7,629,901,935
Territorial – EP	46,180	69,270	138,539
Variation with vs without social distancing	120th day	180th day	360th day
Territorial – GDP	71.43%	77.84%	25.12%
Territorial – EP	71.43%	77.84%	25.12%

Source: Elaborated by the authors.

The data reveal that social distancing establishes less dynamic vulnerabilities both for the value of productive activities and for formal jobs in the state. More relevantly, we observed that, by maintaining social distancing for more days, the economic vulnerability tends to be less accentuated in comparison to a scenario without social distancing. However, as vulnerability is not an economic impact, it is not possible to say clearly what would be the most appropriate time to suspend vulnerability measures, with the greatest effect being between the 120^{th} and 180^{th} days.

5. CONCLUSION

This study aimed to identify the socio-economic instability of municipalities in the Brazilian state of Ceará in the face of the COVID-19 pandemic. The findings showed the effects of the pandemic in an economic context composed basically of the service sector, which is characterized by intense human contact and social interaction. In the case of Ceará, a series of local demographic, social, and economic determinants aggravate the crisis' impacts. The concentration of activities in the metropolitan region and the confluence of human mobility for the region end up creating a strong influence in the numbers for the state. The low HDI and the reduced economic dynamism of the other municipalities, explain the development of a relationship of dependence, which limits the state's economy to the economic potential of the capital city. The combination of these factors results in increasing insecurity, jeopardizing the state's action to face the pandemic without serious economic repercussions. Interregional development policies must be conducted with the aim of decentralizing this dependency.

As for the dynamic vulnerability discussed in this article, it demonstrates that social distancing makes the economy less exposed. This phenomenon usually occurs during the first 120 days, evidence that may guide tailor-made public policies toward specific sectors, mitigating the economic impacts related to the COVID-19 pandemic. Therefore, the weaknesses addressed in this research, based on GDP and employed persons, may lead to different strategies to face the health crisis, whether for each municipality or the states' mesoregions. For example, it is essential for some municipalities to implement instruments to encourage companies and generate wealth directly. In other cases, the government must intensify measures to support and minimize the economic effects of the pandemic, such as the loss of jobs.

Thus, the measurement of vulnerability indices assists in decision making regarding the strategies to reduce the susceptibility of these areas. This method allows a comparison between municipalities in the same state, even though they present very different socio-economic configurations. This was observed in Ceará, where the results show a great variation between the municipalities of Pacatuba, which has the lowest indexes in the state (TV_{GDP} and TV_{EP}, BRL 8.8 million and 60 employed persons, respectively), and Fortaleza (TV_{GDP} and TV_{EP}, BRL 27.9 million and 296.8 thousand employed persons, respectively). Consequently, the variables and indicators used to calculate instability can work as a basis for decisions by local and state governments in the chronology of the economic reopening by sectors, municipalities, and regions, considering the highest weaknesses as the most urgent. Finally, future research may emphasize the measurement of insecurity considering the three stages presented in this study (broad, territorial, and dynamic) in other states or regions considered as regional epicenters in a sanitary crisis such as the COVID-19 pandemic.

REFERENCES

Briguglio, L., Cordina, G., Farrugia, N., & Vella, S. (2009). Economic vulnerability and resilience: concepts and measurements. *Oxford Development Studies*, *37*(3), 229-247.

Decreto n. 33.519 de 19 de março de 2020. (2020). Dispõe sobre as medidas para o enfrentamento da pandemia do novo coronavírus e dá outras providências. Retrieved from https://www.legisweb.com.br/legislacao/?id=391458

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E. … Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, *18*(4), 598-606.

Gompertz, B. (1825, June 16). XXIV. On the nature of the function expressive of the law of human mortality, and on a new mode of determining the value of life contingencies. In a letter to Francis Baily, Esq. F. R. S. & c. *Phil. Trans. R. Soc.*, *115*, 513-583. Retrieved from http://doi.org/10.1098/rstl.1825.0026

Hand, M. S., Eichman, H., Triepke, F. J., & Jaworski, D. (2018). *Socio-economic vulnerability to ecological changes to National Forests and Grasslands in the Southwest*. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Head, B. W., & Alford, J. (2015). Wicked Problems: Implications for Public Policy and Management. *Administration & Society*, *47*(6), 711-739.

Instituto Brasileiro de Geografia e Estatística. (2020a). *IBGE Cidades*. Retrieved from https://cidades.ibge.gov.br/

Instituto Brasileiro de Geografia e Estatística. (2020b). *Comissão Nacional de Classificação (Concla)*. Retrieved from https://concla.ibge.gov.br/busca-online-cnae.html

Jia, L., Li, K., Jiang, Y., Guo, X., Zhao, T. (2020). Prediction and analysis of coronavirus disease 2019. *arXiv:2003.05447*.

Kreuter, M. W., Rosa, C., Howze, E. H., & Baldwin, G. T. (2004). Understanding wicked problems: a key to advancing environmental health promotion. *Health Education & Behavior*, *31*(4), 441-454.

Li, R., Pei, S., Chen, B., Song, Y., Zhang, T., Yang, W., & Shaman, J. (2020, May 01). Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (Sars-CoV2). *Science*, *368*, (6490), 489-493. Retrieved from http://doi.org/10.1126/science.abb3221

Lins-de-Barros, F. M. (2017). Integrated coastal vulnerability assessment: a methodology for coastal cities management integrating socio-economic, physical and environmental dimensions-Case study of Região dos Lagos, Rio de Janeiro, Brazil. *Ocean & Coastal Management*, *149*, 1-11.

Mckercher, B. (2003). SIP (Sars induced Panic) a greater threat to Tourism than Sars (Severe acute respiratory Syndrome. *E-revise of Tourism Research (ERTR)*, *1*(1), 17-18.

Mclafferty, S. (2010). Placing pandemics: geographical dimensions of vulnerability and spread. *Eurasian Geography and Economics*, *51*(2), 143-161.

Ministério do Turismo. (2020). *Dados e fatos*. Retrieved from http://dadosefatos.turismo.gov.br

Nelson, J. K., & Grubesic, T. H. (2018). Oil spill modeling: risk, spatial vulnerability, and impact assessment. *Progress in physical geography: earth and environment*, *42*(1), 112-127.

Rakauskiene, O. G., & Strunz, H. (2016). Approach to reduction of socio-economic inequality: decrease of vulnerability and strengthening resilience. *Economics & Sociology*, *9*(4), 243.

Relação Anual de Informações Sociais. (2018). *Bases estatísticas Rais/Caged*. Retrieved from http://bi.mte.gov.br/bgcaged/login.php

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155-169.

Secretaria de Saúde do Ceará. (2020). Arquivos Coronavírus (COVID-19). *Boletim epidemiológico novo coronavírus (COVID-19) – 26 de março de 2020*. Retrieved from https://www.saude.ce.gov.br/download/arquivos-coronavirus-covid-19/

Sistema de Cadastro de Pessoas Físicas e Jurídicas que Atuam no Setor do Turismo. (2019). *Prestadores de serviços turísticos – Cadastur*. Retrieved from http://dados.turismo.gov.br/cadastur

Siu, A., & Wong, Y. C. R. (2004). Economic impact of Sars: the case of Hong Kong. *Asian Economic Papers*, *3*(1), 62-83.

Samuel Façanha Câmara

https://orcid.org/0000-0002-8333-6997
Ph.D. in Economics and Adjunct Professor of the Graduate Program in Administration at the State University of Ceará (PPGA-UECE). E-mail: samuel.camara@uece.br

Francisco Roberto Pinto

https://orcid.org/0000-0003-2559-1524
Ph.D. in Administration and Associate Professor of the Graduate Program in Administration at the State University of Ceará (PPGA-UECE). E-mail roberto.pinto@uece.br

Felipe Roberto da Silva

https://orcid.org/0000-0001-7902-4432
Master student in Administration, Graduate Program in Administration at the State University of Ceará (UECE). E-mail: felipe.roberto@aluno.uece.br

Felipe Gerhard

https://orcid.org/0000-0002-1117-5960
Ph.D. in Administration from the State University of Ceará (PPGA-UECE)
E-mail: gerhard.sousa@aluno.uece.br