The economic impacts of COVID-19 in Brazil based on an interregional CGE approach

Alexandre A. Porsse¹,² | Kênia B. de Souza¹,² | Terciane S. Carvalho¹ | Vinícius A. Vale¹

¹Department of Economics and Postgraduate Program in Economic Development (PPGDE) of Federal University of Parana (UFPR), Parana, Brazil
²Brazilian National Council for Scientific and Technological Development (CNPq), Brasilia, Brazil

Correspondence
Vinícius A. Vale, Department of Economics and Postgraduate Program in Economic Development (PPGDE) of Federal University of Parana (UFPR), Avenida Professor Luciano Gualberto 632, Curitiba, Parana 32988541935, Brazil.
Email: vinicius.a.vale@gmail.com

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Abstract
This study projects the economic impacts of COVID-19 outbreak on the Brazilian economy using a dynamic interregional computable general equilibrium model. We considered two scenarios. The first scenario has two channels of transmission over the economic system: a negative shock of labour supply due to the rates of morbidity and mortality caused by the pandemic, and a temporary shutdown of nonessential economic activities. The second scenario adds to the first the effects of the government fiscal package adopted to counteract the effects of COVID-19 on the economy. Furthermore, in both scenarios, a sensitive analysis related to the temporality of the shutdown is considered by assuming 3 and 6 months of shutdown. The results indicate a reduction of 3.78% in the national GDP growth rate in Scenario 1 and a reduction of 0.48% in Scenario 2, in 2020, with 3 months of shutdown. With 6 months, the reduction would be greater, 10.90% and 7.64% in Scenarios 1 and 2, respectively. Thus, the government fiscal stimulus considered in this study partially mitigates the reduction in GDP projected under the COVID-19 outbreak. The study also presents sectoral projections at the national and state levels. The estimates indicate reductions in the GDP of most of Brazilian states in both scenarios.
1 | INTRODUCTION

The first case of COVID-19 was registered in China in December 2019. Since then, the virus has rapidly spread across several countries around the world. Due to the rapid increase in the number of cases outside China, the World Health Organization (WHO) classified the COVID-19 outbreak as a pandemic on 11 March 2020. In Brazil, since the first case was confirmed, on 26 February, the outbreak has been growing fast in all the Brazilian states. Until 23 July, 2020, the number of cases and the number of deaths in Brazil were 2,227,514 and 82,771, respectively. Given these numbers and the Brazilian population of 210,147,125, the lethality rate is 3.7% and the mortality rate (per 100,000 inhabitants) is 39.4 (Brazilian Ministry of Health).\(^1\) Furthermore, considering the data reported on the COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)\(^2\) until 23 July 2020, Brazil was the second most affected country regarding confirmed cases and deaths.

The dispersion of cases and deaths among Brazilian regions is remarkable. The state of São Paulo was considered the epicentre at the beginning of the outbreak, concentrating about 430,000 of confirmed cases and more than 20,000 deaths.\(^3\) Besides São Paulo, the disease has spread to other states. The states of Ceará, Rio de Janeiro and Pará have presented a growing number of confirmed cases and deaths in the current stage (until 23 July 2020). Although these states concentrate the cumulative number of cases and deaths, the outbreak has grown also in the South and Central-West regions, mainly in Mato Grosso, Distritto Federal, Paraná and Santa Catarina.\(^4\)

Given this scenario and the fact that there has been no vaccine available to protect against the virus until July 2020, and the intensity of the morbidity and mortality rates observed in several countries, social isolation has been pointed by the WHO and health experts as the most appropriate strategy to control the outbreak spread. Countries that underestimated the disease and postponed effective enforcement actions to social isolation were faced with a collapse of the health system and uncontrolled expansion of cases.

Furthermore, due the potential economic effects of COVID-19 outbreak, many institutions (International Monetary Fund (MF), 2020; The World Bank, 2020; United Nations Conference on Trade and Development - UNCTAD, 2020a, 2020b; World Trade Organization (WTO), 2020a, 2020b) and researchers (Arezki & Nguyen, 2020; Baldwin & Di Mauro, 2020; Boone, 2020; Domingues, Cardoso, & Magalhães, 2020a, 2020b; Haddad, Perobelli, & Araújo, 2020; Haddad, Perobelli, Araújo, & Vassalo, 2020; Maliszewska, Mattoo, & van der Mensbrugghe, 2020; McKibbin & Fernando, 2020a, 2020b; Moura, Esperidião, Ribeiro, Santana, & Andrade, 2020; Oliveira et al., 2020; Ribeiro, Nonnemberg, et al., 2020; Ribeiro, Santana, et al., 2020; Santos, Ribeiro, & Cerqueira, 2020) have discussed these effects.

These studies have pointed many transmission channels and economic effects. Baldwin and Di Mauro (2020), for instance, have discussed the potential economic shock regarding the demand and supply side. On the supply side, it is caused by the closures and travel bans that will reduce productivity, causing temporary drops in employment, by health-shock propagation uncertainty and supply-chain shocks. On the demand side, it is caused mainly by the reduction in household consumption.

Other studies have focused on the economic effects in many countries around the world. IMF (2020) has projected the economic effects for several economies, including Brazil. UNCTAD (2020a) has focused on the global trade impact effects.\(^5\)

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\(^1\) Data obtained at https://covid.saude.gov.br on 23 July 2020. The data must be carefully evaluated since Brazil has not tested COVID-19 on a large scale.

\(^2\) See https://coronavirus.jhu.edu/map.html for more details.

\(^3\) Data obtained at https://covid.saude.gov.br on 23 July 2020.

\(^4\) The spatial pattern of COVID-19 in Brazil has changed rapidly. Updated data may be checked at Brazilian Ministry of Health (https://covid.saude.gov.br).
of COVID-19 epidemic, while UNCTAD (2020b) has focused on COVID-19 shock in developing countries. McKibbin and Fernando (2020b) have simulated seven scenarios regarding the spread of COVID-19 with a dynamic stochastic general equilibrium (DSGE) model and a computable general equilibrium (CGE) model. Considering the scenarios where the pandemic occurs in all countries in different degrees, McKibbin and Fernando (2020a) found, for example, a reduction from 1.9% to 8.0% of the Brazilian GDP, depending on which epidemiological scenario is adopted.

Global effects of the pandemic were also analysed by Gössling, Scott, and Half (2020) and Ramos, Ferreira, Cruz, and Barata (2020) using the World Input–Output Database (WIOD). Gössling et al. (2020) assessed the differential regional impacts and implications of the reported impacts of COVID-19 on global tourism until the end of March 2020. They also showed the damage to the tourism economy over 2020 caused by travel restriction and stay-at-home policies. These measures have negatively affected the tourism sector, mainly the subsectors of travel, cruises, and accommodation. For example, in the accommodation sector, by 21 March, guest numbers have declined by 50% or more, affecting mainly countries with large number of COVID-19 cases, such as Greece and Italy.

Ramos et al. (2020) simulated a half drop in the demand of non-essential sector. The authors have divided the WIOD sectors into essential and non-essential sectors and considered a symmetric shock in all countries. Since countries present different economic structure in terms of productive leakages and final demand composition, the authors have identified how they may be affected by consumption pattern changes. The results showed a reduction of 33.1% in world trade. In terms of value added, China and other Asian countries would be the most affected countries. Regarding the trade balance, their results show that developing countries, including Brazil, would have greater drops in imports than exports, improving their trade balance.

Regarding the economic impact in Brazil, Haddad, Perobelli, and Araújo (2020) developed a methodology to assess the daily economic impacts of control strategies for mitigating the effects of COVID-19 outbreak using input–output analysis. They applied the methodology to inform regional and national governments in Brazil on the potential and sectoral economic costs of different strategies of lockdown measures. Haddad, Perobelli, Araújo, and Vassalo (2020) evaluated the economic impacts of COVID-19 outbreak on tourism concerning the demand reduction in the state of São Paulo by also using an interregional input–output model. Domingues et al. (2020a) used a general equilibrium model to project the economic impacts of an emergency demand for health-related activities, while Domingues et al. (2020b) showed that the economic impacts of COVID-19 caused by the negative employment shock tend to be worse for the poorest households in Brazil. Ribeiro, Nonnemberg, et al. (2020) and Oliveira et al. (2020) have focused on the potential effects on Brazilian foreign trade.

In this context, this study aims to simulate the impacts of COVID-19 outbreak on the Brazilian economy using a dynamic interregional computable general equilibrium (CGE) model. The simulations consider three transmission channels through the economy related to the outbreak and its effects. The first channel considers a negative labour supply shock calculated from estimations of morbidity (number of people infected by the virus and temporarily unable to work) and mortality (number of people who die due to infection disease). The dimension of this shock has been based on information from the epidemiological scenarios of COVID-19 outbreak projected by the Imperial College London COVID-19 Response Team (Walker et al., 2020). The second channel considers a temporary shutdown or reduction of nonessential economic activities, mainly services, due to social isolation. Finally, the third channel incorporates the effects of fiscal stimulus announced by the Brazilian Government to mitigate the contractionary economic effects of the disease.

The projections are divided into two scenarios: Scenario 1 considers the first two transmission channels related to the COVID-19 outbreak and the social isolation; and Scenario 2 adds the government’s countercyclical fiscal policies to the first one. A sensitivity analysis is also carried out by considering the duration of the non-essential economic activity’s shutdown. Uncertainty about the evolution of COVID-19 made it difficult to anticipate how long social isolation measures should remain, raising the importance of this sensitivity analysis. Therefore, we simulate a shutdown of 3 and 6 months in both scenarios.

The methodology proposed by Haddad, Perobelli, and Araújo (2020) has been also applied to Colombia. See Bonet-Morón et al. (2020).
It is worth mentioning that this study does not intend to be exhaustive in terms of incorporating the derailment of wide range of government policies that can potentially contribute to counteract the contractionary economic effects. Many fiscal measures are still in the process of formulation, approval, and regulation by the competent authorities. Furthermore, economic results are sensitive to the choice of the epidemiological scenario and, depending on the evolution of the number of infected, the mortality rate and the practices of social isolation, they may be more intense or not.

Therefore, the main contribution of this paper is to estimate the economic impact of COVID-19 outbreak in Brazil with regional and sectoral detailing, obtained from a scientific modelling framework that integrates information from the economic system and epidemiological scenarios. The results obtained can be used to subsidize policymakers and other agents to deal with the consequences of the disease.

This study is organized as follows. Section 2 provides a brief presentation of the economic modelling framework used to project the economic impacts for Brazil. Section 3 presents details about each scenario. Section 4 reports and discusses the main results. Finally, Section 5 presents the final considerations.

2 | THE DYNAMIC CGE MODEL

In order to simulate the impacts of COVID-19 outbreak on the Brazilian economy, we used a dynamic and inter-regional computable general equilibrium (CGE) model, which is named TERM-UF. This model is fully disaggregated by 27 Brazilian States and 29 economic sectors, as detailed in Table 1. Its theoretical structure and solution mechanisms follow the Australian TERM model (Horridge, 2012; Wittwer, 2017).6

The database was constructed using the regionalization procedure developed by Horridge (2006). The first step consisted in calibrating the static version of a national CGE model based on the input–output database for Brazil in 2015. The second step uses a large set of secondary data,7 which allows for the identification of the regional structure of production and consumption at the regional level. Finally, the interregional trade flows are estimated by applying a gravitational approach.

CGE models are a useful tool to simulate economic scenarios, since they incorporate a detailed set of behavioural economic equations, forming a system that recognizes the interdependence of transactional relationships between different economic agents: firms, families, government, and the external sector. In the TERM-UF model, all these relationships are established at the regional level, that is, the Brazilian States, and aggregated for the entire economy allowing for the generation of results at the national and regional levels.

TERM-UF is composed of blocks of equations that determine relationships between supply and demand, according to optimization assumptions and market-clearing conditions. In addition, several national aggregates, such as the aggregate employment, GDP, investment, and price indexes, are defined in these blocks. The economic activities minimize production costs subject to a technology of constant returns to scale in which the combinations of intermediate inputs and primary factors (aggregated) are determined by fixed coefficients (Leontief). There is the substitution of domestic and imported goods via the prices in the composition of inputs according to the function of the constant elasticity of substitution (CES). A CES specification also controls the allocation of a domestic compound among the various regions. There is also substitution between capital and labour in the composition of the primary factors through CES functions (Carvalho, Domingues, & Horridge, 2017).

There is a representative household for each region consuming domestic and imported goods. The choice between domestic and imported goods (from other countries) is held by a CES (Armington assumption) specification, which is part of a household demand system of preferences, combining CES and Klein-Rubin functions. The

6For the detailed theoretical structure and more information on TERM see: www.copsmodels.com/term.
7The data includes regional output shares, regional investment shares and regional household consumption shares by sector and region from IBGE (the Brazilian Institute of Geography and Statistics), RAIS (Annual List of Social Information) and POF (Household Budget Survey). Furthermore, it includes regional government expenditure shares, regional export shares and regional import shares by commodities and region from IBGE, SECEX and RAIS. Finally, the data also considers the regional population from IBGE.
The specification gives the linear expenditure system (LES), in which the share of expenditure above the subsistence level for each good represents a constant participation of the total subsistence expenditure of each family.

The goods of a region are compounded by the basic values plus trade and transport margins. The margin share in the delivery price is a combination of origin, destination, goods and source (domestic or imported). Margins on goods from one region to another can be produced in different regions. In addition, there is substitution between suppliers of margins, according to a CES function.

The model operates with market equilibrium for all goods, both domestic and imported, as well as the market factors (capital, and labour) for each region. The purchase prices by user (producers, investors, households, exporters, and government) are the sum of the basic values, sales taxes (direct and indirect) and margins (trade and transport). Sales taxes are treated as ad valorem taxes on basic flows. Demands for margins (trade and transport) are proportional to the flow of goods to which the margins are connected.

The dynamic of the model is of the recursive type, making it possible to project the simulation results for the time horizon of interest. Then, investment and capital stock follow mechanisms of accumulation and inter-sectoral shift from pre-established rules related to the depreciation and rates of return. The labour market has an element of intertemporal adjustment of real wages. It is assumed that the demand for labour determines the number of workers used in production and that real wages are rigid in the short run, but flexible in the long run. The base year for the calibration of the TERM-UF model for the Brazilian economy is 2015. Its database specification takes into account information from several sources, such as the tables of resources and uses (TRUs) of 2015 of the System of National Accounts (SNA) of the Brazilian Institute of Geography and Statistics (IBGE, 2019a), Annual List of Social Information (RAIS) of the Secretariat of Labor, Ministry of Economy (2019a), Secretariat of Foreign Trade (Secex) of the Ministry of Economy (2019b) and Household Budget Survey (POF) (IBGE, 2019b).

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**TABLE 1** TERM-UF model structure

| Economic Agents | Regions |
|-----------------|---------|
| A representative firm for each of the 29 sectors and each of the regions | 27 Brazilian States |
| A representative household for each region | |
| Government | |
| External Sector | |

**Sectors**

- Agriculture
- Livestock
- Silviculture
- Mining
- Food and Beverages
- Others in the Industry
- Chemicals
- Energy and Water
- Construction
- Trade
- Transports
- Public Health
- Food
- Information and Communication
- Financial
- Real Estate Activities
- Legal and Consulting Activities
- Architectural and Engineering Activities
- Other Scientific Activities
- Non-Real Estate Rentals
- Other Administrative Sector
- Surveillance and Security
- Public Administration
- Public Education
- Private Education
- Public Health
- Private Health
- Artistic Activities
- Associative Organizations and Others

Source: Elaborated by the authors.
was updated yearly until 2019, considering the macroeconomic behaviour of the Brazilian economy observed in this period. The simulations presented are based on updated data from 2019 and the changes caused by COVID-19 in 2020.

The simulations with the TERM-UF model involve the specification of a baseline (reference scenario) and policy scenarios. The baseline represents a reference path at a national level, given the expected behaviour of economic variables reflected mainly on macroeconomic aggregates (GDP and investment), which follows the trend of the recent period. In this study, the base scenario assumes, for example, that national GDP would grow by 2.2% in 2020, as expected by the Central Bank's Focus report before the proliferation of COVID-19 in Brazil. The regional economic results are calculated endogenously and guarantee the consistence with the baseline at the national economy level. In its turn, the policy scenario represents an exogenous "disruption" in the economic system that affects the decision of economic agents, causing a deviation from the equilibrium of the reference scenario. This deviation can be positive or negative, depending on the context of the simulated change. For the scenarios presented in this paper, all changes related to isolation and the shutdown trigger adverse deviations on the main economic variables, as illustrated in Figure 1.

3 | POLICY SCENARIOS

For the two policy scenarios simulated, we used a combination of information about the epidemiological scenario, sectoral isolation effects and fiscal policy measures. For both scenarios, all exogenous variations were imposed at the national level. Therefore, all regional differences are calculated endogenously. For Scenario 1, we incorporated a supply shock in the workforce resulting from the expected morbidity and mortality rates due to COVID-19, as well as a fall in activity in specific economic sectors due to social isolation. For Scenario 2, we kept the shocks assessed in Scenario 1 in addition to governmental fiscal measures planned so far by the Federal Government. Furthermore, in both scenarios, a sensitive analysis related to the temporary shutdown is considered. We simulated Scenarios 1 and 2 with 3 and 6 months of shutdown.

3.1 | Scenario 1: labour supply shock and reduction in sectoral activity

The first transmission channel in Scenario 1 assumes that the effects of COVID-19’s morbidity and mortality should cause a shock to the labour supply in the national economy due to the time necessary for the treatment and

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9Focus – Market Report of 02/21/2020. URL: www.bcb.gov.br/publicacoes/focus/21022020. Accessed 27 February 2020.
recovery of infected people as well as those who will die of the disease. The dimensioning of this shock was based on the epidemiological estimates for COVID-19 in Brazil elaborated by the study of the Imperial College London COVID-19 Response Team (Walker et al., 2020).\textsuperscript{10} Due to the measures of social isolation taken in Brazil and considering that the official estimates may underestimate the number of infected people in the country, we decided to use the parameters of the suppression scenarios of the Imperial College London as a reference for calibrating the labour supply shock.

The calibration of the supply shock considers a scenario of suppression with three main characteristics. First, the basic reproduction number (average number of secondary infections due to a typical infection in an unrestricted epidemic and a fully susceptible population) is 3. Second, the scenario considers an isolation rate of 75%. And third, about 23% of the population is infected. Assuming a labour force participation rate of 45%,\textsuperscript{11} and considering infections as temporary losses (two weeks in a year) and deaths as permanent losses, the labour supply shock was dimensioned at $-1.04\%$.

The second transmission channel in Scenario 1 refers to the effects of the economic activity reduction associated with social isolation. The isolation of the population was considered to potentially paralyse several activities in the economy for 3 months (a) or 6 months (b), especially those that generate overcrowding. Although some activities continue via home office, the hypothesis is that during these months, activities such as trade, transport, accommodation, food services (restaurants), Other administrative activities, artistic activities, associative organizations and others will be totally or partially paralysed. For the subsectors attracting crowds (shopping malls, artistic and cultural activities, among others), a reduction of 100% in the economic activity was assumed, while for the subsectors where social distancing can be maintained, a decrease of 50% was assumed. The shocks where calibrated according to the dimensioning of the workforce in each sector from the Continuous National Household Survey (PNADC)\textsuperscript{12} microdata (IBGE, 2020).

We considered a shutdown of 3 and 6 months in the year of 2020 for all states. These simulations allow us to highlight the most fragile regions. In other words, we can identify regions that could suffer more negatively the impacts due to the restrictions imposed by the COVID-19 outbreak.

Nonetheless, it is important to highlight as a limitation of the study that our results do not consider the fact that social distancing and stoppage of productive activities were not homogeneous across the states, and the outbreak was also unevenly spread. Policies of social distance were determined by local authorities, and initially, regions of the Southeast, Northeast and North were the most affected by the virus. By July 2020, those regions reached a stable or declining number of cases, however the number of confirmed cases increased in the South and Midwest regions.

3.2 | Scenario 2: government fiscal stimulus measures

Scenario 2 involves the same shocks specified for Scenario 1 plus the shocks considering the increase in government and household consumption associated with the fiscal stimulus measures formulated by the Federal and State Governments. In this way, the scenario allows us to enquire in what extent the fiscal package contributes to the alleviation of the contractionary economic effects of COVID-19 in Brazil. It is worth noting that this simulation was carried out in a short-run context since it was assumed that the expansion of public expenditure will be financed by public deficits. We briefly discuss the long-run potential implications in the final remarks section.

\textsuperscript{10}The research by the Imperial College London COVID-19 Response Team (2020) estimated five different scenarios. Scenario (1) considers that no mitigation measures are carried out in the country. Scenario (2) includes mitigation measures and horizontal social distance ranging between 35% and 45% of the population. Scenario (3) incorporates to Scenario (2) the intensification of the social distance of the elderly population in order to reduce their social contact rate by 60%. And Scenario (4) is characterized as one of suppression associating the social isolation of 75% of the population to different epidemiological triggers according to the mortality rates per 100,000 inhabitants. Estimates in all scenarios are also conditioned by different factors of epidemiological reproduction (R0 ranging from 2.4 to 3.3).

\textsuperscript{11}We used the observed rate for 2019.

\textsuperscript{12}In Portuguese: “Pesquisa Nacional por Amostra de Domicílios Contínua.”
The calibration of these shocks was based on the impacts of the various governmental measures on the primary result of the government in 2020, according to the report of the Fiscal Policy Observatory from IBRE-FGV. Besides a wide-ranging set of governmental measures, for simulation purposes, those measures which would imply increases were considered in the public expenditure, such as new expenses created and exceptional finance aid to state and municipal governments. The stimulus measures were estimated to represent an impact on the public consumption of R$ 260.2 billion, corresponding to approximately 3.5% of the GDP. In Scenario 2, this impact was assumed to correspond to an exogenous increase in government expenditure.

For simulation purposes, the emergency assistance to low-income people was also considered to represent a direct effect on household consumption. Considering the number of households potentially benefited by this measure based on information from the PNADC microdata and calculating the impact on household income, a potential impact on household consumption was estimated to be of 2.23%. It is worth mentioning that the amount associated with this measure was not incorporated into the government’s consumption shock to avoid double counting.

4 | RESULTS

4.1 | National Results

Figure 2 presents the GDP growth forecast (%) in Scenarios 1 and 2 compared to the Central Bank’s projection for 2020 before COVID-19 outbreak. Considering the 3 months of shutdown, the Brazilian GDP in 2020 would reduce 3.78% in Scenario 1a. Adding the Government fiscal stimulus, Scenario 2a, the reduction would be smaller, 0.48%. Further, considering the uncertainties about the outbreak and need for social isolation, the figure also shows the

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13See: https://observatorio-politica-fiscal.ibre.fgv.br. Accessed: 26 May 2020.
projection with 6 months of shutdown in non-essential economic activities—Scenarios 1b and 2b. In this case, the Brazilian GDP would reduce 10.90% in Scenario 1b and 7.64% in Scenario 2b.

These results show how the economic effects are sensitive to the shutdown duration. Furthermore, they also show that fiscal stimulus considered in Scenario 2 are not able to mitigate all negative effects caused by the COVID-19 outbreak, even in the most optimistic scenario in which the shutdown remains for only three months. The negative effect is clearer when the Central Bank Projection is used as benchmark. Before the COVID-19 outbreak, the Brazilian Central Bank has projected a GDP increase of 2.20% in 2020.

Table 2 presents the macroeconomic results as percentage (%) deviation in relation to the reference scenario (baseline). As shown, the GDP would present a deviation of −5.85% in Scenario 1 with 3 months of shutdown in relation to the reference scenario. This reduction is calculated based on the difference between baseline, with GDP growth of 2.2% and the policy scenario, with a variation of −3.78% in GDP. The deviation would be −2.63% with the fiscal stimulus – Scenario 2. Considering the longer shutdown, 6 months, the GDP deviations in Scenario 1 and 2 would be −12.82% and −9.63%, respectively.

The table also shows the estimated deviation in household consumption. It would represent a negative deviation of 10.77% and 8.54% in Scenarios 1 and 2, respectively, with 3 months of shutdown. If the period of 6 months is considered, the effect would be a negative deviation of −23.11% and −20.88%. The smaller reduction in household consumption in Scenario 2 is due to the income transfer policies that were considered in this scenario and partially mitigates the pandemic effects.

The sectoral activity results can be seen in Figures 3 and 4. Figure 3 presents the results of Scenario 1 with 3 and 6 months of shutdown of non-essential activities, while Figure 4 shows the results considering Scenario 2. The reduction in the activity level of Accommodation, Artistic Activities, Associative Organizations and Others, Food, Trade and Transportation is the same in both scenarios since these sectors have partially or completely stopped for 3 or 6 months.

The results show that the reduction in labour supply and the shutdown would affect not only non-essential sectors, but indirectly all other sectors of the Brazilian economy in Scenario 1. There are high negative effects in private education, food and beverages, livestock and others in Industry. The sectoral deviation in relation to reference scenario is sensitive to the longer shutdown. The longer shutdown may intensify the sectoral losses, as shown by Figure 3(a) and Figure 4(a).

In Scenario 2, in turn, the sectors that concentrate public expenditures show a positive deviation in relation to the reference scenario (baseline), that is, public administration, public education and public health. The other sectors, in general, have their negative deviations slightly mitigated by indirect and induced effects of fiscal policy.

Furthermore, it is important to highlight the results of the private health sector. Although an increase in the health expenditure is expected during the pandemic, our simulations show a negative effect on the sector. This result is explained by the fact that our scenarios do not consider this private health expenditure exogenously since there is a lack of data on this. Thus, we assess the direct and indirect effects (via the production chain) of the stoppage of non-essential activity, including these effects in the private health sector. If available, these estimates may be included in future studies.

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**TABLE 2** Macroeconomic results (% deviation in relation to the reference scenario, 2020)

| Indicators       | (a) 3 months of shutdown | (b) 6 months of shutdown |
|------------------|--------------------------|--------------------------|
|                  | Scenario 1 | Scenario 2 | Scenario 1 | Scenario 2 |
| GDP              | −5.85      | −2.63      | −12.82     | −9.63      |
| Household Consumption | −10.77    | −8.54      | −23.11     | −20.88     |

Source: Elaborated by the authors based on the model’s results.

14That is: $\text{PIB}_t = \left[\left(\frac{1}{1-0.0037}\right) - 1\right] \times 100 = -5.85\%$. 
4.2 Regional Results

Figures 5 and 6 show the GDP deviations (%) in Scenarios 1 and 2 in relation to the reference scenario for all Brazilian States. The figures show the deviations with 3 and 6 months of shutdown, respectively. In summary, it is possible to observe reductions in GDP for all states in Scenario 1 with 3 and 6 months of shutdown. All deviations are less negative in Scenario 2 due to the fiscal policy effects.15

In general, these results highlight Brazilian states that would be more economically fragile and, therefore, would suffer the greatest losses due to the impacts of the pandemic and the measures of social distancing and stoppage of supposedly non-essential activities considered. In Scenario 1, on one hand, the five largest deviations are observed for Rondônia (RO) with $-7.64\%$ and $-16.47\%$, for 3 and 6 months of shutdown, respectively, Acre (AC) with $-7.23\%$ and $-15.62\%$, Goiás (GO) with $-7.02\%$ and $-15.24\%$, Rio Grande do Sul (RS) with $-6.83\%$ and $-14.63\%$, and Piauí

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15Table A1 in the Appendix presents the GDP deviations (%) in relation to the reference scenario in the two scenarios.
On the other hand, the five smallest deviations are observed for Distrito Federal (DF), with $-3.17\%$ and $-7.50\%$; Rio de Janeiro (RJ), with $-4.11\%$ and $-9.28\%$; Roraima (RR), with $-4.14\%$ and $-8.95\%$; Sergipe (SE), with $-4.76\%$ and $-10.46\%$; and Espírito Santo (ES), with $-5.37\%$ and $-10.46\%$. Furthermore, it is also possible to highlight the negative deviations of São Paulo (SP) with $-5.98\%$ and $-13.03\%$, which is an important result since São Paulo accounts for almost 30\% of the entire Brazilian economy.

In Scenario 2, which incorporates the effects of government measures, the largest deviations from the reference scenario are observed for Rondônia (RO), with $-5.06\%$ and $-14.15\%$; Goiás (GO), with $-4.47\%$ and $-12.87\%$; Acre (AC), with $-4.38\%$ and $-13.13\%$; Santa Catarina (SC), with $-4.34\%$ and $-12.12\%$, and Rio Grande do Sul (RS), with $-4.28\%$ and $-12.17\%$. The smallest negative deviations, in turn, are observed for Sergipe (SE), with $-0.81\%$ and $-6.53\%$; Alagoas (AL), with $-1.47\%$ and $-7.97\%$; Mato Grosso do Sul (MS), with $-1.64\%$ and $-8.47\%$; Tocantins (TO), with $-1.86\%$ and $-9.06\%$, and Espírito Santo (ES), with $-1.93\%$ and $-8.34\%$. Furthermore, Distrito Federal (DF), Roraima (RR) and Rio de Janeiro (RJ) presented positive deviations in Scenario 2 with 3 months of shutdown, $2.10\%$, $0.97\%$ and $0.35\%$, respectively.
In both scenarios, the smallest deviations are observed for regions with less participation of services considered non-essential, and with greater participation mainly in agriculture, livestock and the entire industrial complex for the production and distribution of food and beverages. In Scenario 2, the fiscal policies mitigate the effects of COVID-19 outbreak on the economy, but they are not enough to reverse the negative results for most of the regions. In general, in Scenario 2, the economies that have a larger share of the government in GDP have presented better results than the others.

5 | FINAL CONSIDERATIONS

This study has projected the economic impacts of COVID-19 outbreak in Brazil. Due the environment of uncertainties regarding the epidemiological progress of the disease and its economic consequences, it contributes to society by providing detailed information at national and regional levels that can be useful to subsidize actions to deal with the economic consequences of the disease.
The projections were simulated through a dynamic interregional computable general equilibrium model. Two scenarios were simulated. Scenario 1 accesses two economic transmission channels of COVID-19 outbreak: (i) a reduction in labour supply due to the effects of morbidity and mortality; and (ii) a reduction in activity levels of specific sectors that are affected by the need of social isolation to combat the spread of the disease. Scenario 2 assesses the effects of the Government fiscal stimulus to counteract the contractionary effects of the disease. Furthermore, in both scenarios, a sensitive analysis related to the shutdown duration is considered. We simulated Scenarios 1 and 2 allowing for 3 and 6 months of shutdown. This sensitive analysis is important since the measures of social distancing and stoppage of activities in the Brazilian states have not been adopted homogeneously. These simulations have allowed us to highlight the most fragile regions.

Considering 3 months of shutdown due to social isolation, Scenario 1 projects a reduction of 3.78% in the national GDP growth rate for 2020. If fiscal stimulus is accounted for, the negative effect is partially mitigated, with a reduction projection of 0.48% in the national GDP for 2020. Considering a longer shutdown period, greater losses are expected in both scenarios – a decrease of 10.90% in the GDP growth rate in Scenario 1 and of 7.64% in Scenario 2. Regarding the regional results, projections indicate reductions in the GDP for most of the Brazilian States.
in both scenarios. Some economies are more vulnerable in relation to the partial closure of non-essential activities, such as Rondônia, Acre and Goiás. Therefore, the role of government measures to combat the economic crisis becomes even more important for these economies. In addition, the study did not consider the negative impacts resulting from a reduction in international trade, which can cause even greater effects, notably in the most exporting regions (such as São Paulo, Rio de Janeiro, Minas Gerais and Rio Grande do Sul).

It is noteworthy that the projections of this study are conditioned to the hypotheses considered about the perspectives of epidemiological evolution of the disease and the shutdown duration. Therefore, variations in these

**FIGURE 5** GDP deviations (%) of Scenarios 1 and 2 with 3 months of shutdown in relation to the reference scenario, 2020.
Source: Elaborated by the authors based on the model's results

**FIGURE 6** GDP deviations (%) of Scenarios 1 and 2 with 6 months of shutdown in relation to the reference scenario, 2020.
Source: Elaborated by the authors based on the model's results
parameters may affect the projected results. In particular, the epidemiological scenario assumes the adoption of social isolation, which may not be confirmed at the required level. If the isolation is not met, the number of infected people may increase significantly, also increasing the loss in the supply of work due to morbidity and mortality, and, consequently, worsening the economic results.

Regarding the countercyclical effects associated with the fiscal stimulus, two limitations should be raised and could be addressed in future research. First, the income effects from transfers were measured considering the consumption pattern of a single representative household, hence we did not capture the heterogeneity across households. Additionally, COVID-19 has increased unemployment and reduced income, affecting mainly informal and low-income jobs. Both of those aspects raise income inequality issues, which could be better addressed in a model with household consumption and wages divided by income groups.

Second, our simulations did not evaluate aspects related to how the expansion of government expenditure could be financed in the long term. In spite of the emergence of using fiscal policy to mitigate the recessive effects caused by COVID-19 in the short run, the long-term economic dynamic could be negatively affected due the potential expansion of public debt and its consequences on the future tax burden. This concern stems from the high public spending required to combat the pandemic, including transitory expenses for public health and policies to mitigate the economic and social effects. Furthermore, public revenues had also dropped abruptly. In Brazil, this is politically sensitive since the country was in a process to adjust public accounts. Recently, a constitutional amendment was approved (spending cap and social security reform) and others were under discussion. However, in the new context, part of the transitory expenses, including those for social assistance, are expected to continue for some time. Thus, future research needs to advance for achieving a better comprehension about the intertemporal economic effects of the disease, which may include aspects related to fiscal sustainability.

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ORCID

Alexandre A. Porsse https://orcid.org/0000-0002-2858-9043
Kênia B. de Souza https://orcid.org/0000-0002-6306-2044
Terciane S. Carvalho https://orcid.org/0000-0002-1082-1609
Vinicius A. Vale https://orcid.org/0000-0001-5869-9860

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**APPENDIX A.**

**TABLE A1** GDP deviation (%) of Scenarios 1 and 2 in relation to the reference scenario, 2020

| Brazilian States | (a) 3 months of shutdown | (b) 6 months of shutdown |
|------------------|--------------------------|--------------------------|
|                  | Scenario 1 | Scenario 2 | Scenario 1 | Scenario 2 |
| RO Rondônia      | −7.64      | −5.06      | −16.47     | −14.15     |
| AC Acre          | −7.23      | −4.38      | −15.62     | −13.13     |
| AM Amazonas      | −5.78      | −3.02      | −12.52     | −10.00     |
| RR Roraima       | −4.14      | 0.97       | 8.95       | 4.04       |
| PA Pará          | −5.56      | −2.19      | −12.40     | −9.40      |
| AP Amapá         | −6.16      | −2.56      | −13.16     | −9.88      |
| TO Tocantins     | −5.62      | −1.86      | −12.51     | −9.06      |
| MA Maranhão      | −6.00      | −2.72      | −13.29     | −10.33     |
| PI Piauí         | −6.82      | −3.86      | −14.83     | −12.33     |
| CE Ceará         | −6.50      | −3.85      | −13.98     | −11.50     |
| RN Rio Grande do Norte | −6.02  | −2.72 | −13.23 | −10.14 |
| PB Paraíba       | −6.02      | −2.38      | −13.23     | −9.81      |
| PE Pernambuco    | −6.58      | −3.74      | −14.22     | −11.53     |
| AL Alagoas       | −5.41      | −1.47      | −11.90     | −7.97      |
| SE Sergipe       | −4.76      | −0.81      | −10.46     | −6.53      |
| BA Bahia         | −6.51      | −3.71      | −14.21     | −11.58     |
| MG Minas Gerais  | −6.66      | −3.75      | −14.75     | −11.99     |
| ES Espírito Santo| −5.37      | −1.93      | −11.84     | −8.34      |
| RJ Rio de Janeiro| −4.11      | 0.35       | −9.28      | −4.51      |
| SP São Paulo     | −5.98      | −2.99      | −13.03     | −10.04     |
| PR Paraná        | −6.53      | −3.84      | −14.16     | −11.65     |
| SC Santa Catarina| −6.81      | −4.34      | −14.58     | −12.20     |
| RS Rio Grande do Sul | −6.83  | −4.28 | −14.63 | −12.17 |
| MS Mato Grosso do Sul | −5.38  | −1.64 | −11.99 | −8.47 |
| MT Mato Grosso   | −5.73      | −2.50      | −12.70     | −9.76      |
| GO Goiás         | −7.02      | −4.47      | −15.24     | −12.87     |
| DF Distrito Federal | −3.17 | 2.10 | −7.50 | −1.94 |

*Source: Elaborated by the authors based on the model’s results.*
Resumen. Este estudio pronostica los impactos económicos de COVID-19 en la economía brasileña mediante el uso de un modelo dinámico interregional de equilibrio general computable. Se consideraron dos escenarios. El primer escenario tiene dos canales de transmisión sobre el sistema económico: una conmoción negativa de la oferta de mano de obra debido a las tasas de morbilidad y mortalidad causadas por la pandemia, y un cierre temporal de las actividades económicas no esenciales. El segundo escenario añade al primero los efectos del paquete fiscal del gobierno adoptado para contrarrestar los efectos de COVID-19 en la economía. Además, en ambos escenarios se tiene en cuenta un análisis de sensibilidad relacionado con la temporalidad del cierre, el cual asume 3 y 6 meses de cierre. Con 3 meses de cierre, los resultados indican para 2020 una reducción del 3.78% en la tasa de crecimiento del PIB nacional en el Escenario 1 y una reducción del 0.48% en el Escenario 2. Con 6 meses, la reducción sería mayor, del 10.90% y el 7.64% en los Escenarios 1 y 2, respectivamente. Por tanto, el estímulo fiscal del gobierno considerado en este estudio mitiga parcialmente la reducción del PIB proyectada en el marco de la pandemia de COVID-19. El estudio también presenta proyecciones por sector a nivel nacional y estatal. Las estimaciones indican reducciones en el PIB de la mayoría de los estados brasileños en ambos escenarios.

抄録：本研究では、計算可能な多地域動学的モデルを用いて、COVID-19アウトブレイクのブラジル経済に対する経済的影響を予測する。本稿では2つのシナリオを検討する。第1のシナリオには、経済システム全体に波及する2つの経路がある。すなわち、パンデミックによる罹病率と死亡率による労働供給に対するマイナスのショックと、不必要な経済活動の一時的な停止である。第2のシナリオは、COVID-19の経済への影響を阻害するために採用された政府の財政パッケージの影響を第1のシナリオに加えたものである。さらに、3ヶ月と6ヶ月の操業停止を仮定して、操業停止の時間性に関連する感度分析を両シナリオにおいて考慮した。その結果、操業停止期間が3ヶ月の場合で2020年の国内GDPの成長率は、シナリオ1では3.78%、シナリオ2では0.48%低下し、操業停止期間が6ヶ月の場合、低下率はシナリオ1とシナリオ2でそれぞれ10.90%と7.64%とさらに悪化した。このように、本研究で検討した政府による財政刺激は、COVID-19発生の下で予測されるGDPの低下を部分的に緩和する。また、国および州レベルでの部門別の予測も行った。両シナリオとも、ブラジルのほとんどの州のGDPが減少する。