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COVID-19, public agglomerations and economic effects: Assessing the recovery time of passenger transport services in Brazil

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ABSTRACT

The outbreak of COVI-19 and the restrictive measures on the mobility of people in Brazil have raised serious concerns about the survival and recovery of passenger transport companies, especially those that generate public agglomerations. There are some policy proposals that aim to recover this set of sectors in the face of the adverse effects of the COVID-19 outbreak. This study contributes to this debate in course and analyzes the economic effects of two scenarios of recovery for this type of transport services in the Brazilian economy up to the end of 2022: (i) one with a 50% recovery until the end of 2021 and (ii) another with a 50% sectorial recovery until June 2022. This distinction allows us to assess the impact of the speed of recovery. In both scenarios, we also consider likely changes in the labor market, family preferences, and government spending. To accomplish this task, we developed a dynamic computable general equilibrium model that recognizes a Social Accounting Matrix (SAM) and has details of the transport sectors. The main findings suggest that the drop in these transport services is the main contributing factor to the decline in the Brazilian GDP growth (−2.2%) in the period of social distance measures. However, faster recovery of these sectors can generate a marginal effect of 0.5 percentage points on GDP at the end of 2021. In the recovery period, due to the redistributive effects of income, the family demand for public transport is expected to grow post- COVID-19 outbreak, while the demand for private transport is reduced, especially in the basket of goods of the poorest households. Vehicle, bus, and aircraft manufacture seems sensitive to the recovery time of the demand for transport services with public agglomerations.

1. Introduction

The economic effects of the COVID-19 outbreak are consequences of factors directly related to the infection and to preventive measures to avoid the spread of disease. On one hand, direct consequences include the contagiousness. The COVID-19 outbreak poses additional threats compared to other global disease outbreaks, such as Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), and Ebola. Although estimates indicate that COVID-19 has a lower fatality rate, the coronavirus spreads more easily than those diseases (Callaway et al., 2020). Thus, COVID-19 tends to spread quickly across regions and countries, which has infected a large portion of the population and, therefore, caused serious public health concerns. On the other hand, indirect consequences include preventive measures, such as social distancing and interruption of some economic activities, especially those that involve agglomeration of people, such as service activities. Other factors, such as the duration of the isolation measures, the magnitude and persistence of the direct economic effects, and the size of the economic spillovers and spillbacks across countries, may also intensify the adverse effects related to the pandemic (Kohlscheen et al., 2020).

In Brazil, the first case of COVID-19 was diagnosed on February 26, 2020, and the worst phase of the pandemic has been in the first quarter of 2021. On May 16, 2021, the total number of confirmed infections and deaths reached 15,627,475 and 435,751 people, respectively, with the first still showing an upward trend (Brasil, 2021a). The main measure adopted in Brazil to slowdown the spread of the disease was the partial shutdown of some non-essential economic activities. In April 2020, marked by the full lockdown, several sectors were strongly impacted, such as industry (−26.12%), retail sales (−18.6%), and services (−17.6%). By December 2020, the industry had recovered and ended

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2020 with a positive performance (+4.38%). Some industrial sectors have failed to recover, such as the food and vehicle manufacturing industries. The retail trade sector behaved similarly to industry and ended 2020 with a positive performance (+0.62%). Even so, Brazil's GDP fell by 4.06% in 2020, compared to the positive GDP growth rate of 1.14% in 2019. This result was due to the cumulative negative performance of the services sector (−4.31%) (IBGE, 2021a; 2021b; 2021c; 2021d).

Among the services, transportation services were particularly affected. Passenger transport tends to be negatively impacted by the COVID-19 crisis since social distance has imposed adjustments and safety rules that end up reducing air travels (e.g., domestic and international), urban and inter-cities and inter-states travels, affecting the passenger flow, operations and revenue generation for firms. In Brazil, at the end of March 2020, there was a 58% reduction in human mobility in places such as public transport terminals, for example, metro, bus, and train stations. In April, this change in human mobility was −46% (Google, 2021). Until April 2020, road and air transport accumulated declines of 28.48% and 80.30%, respectively, in sales volume. Despite the following months of recovery, both road transport (−8.82%) and air transport (−31.94%) accumulated losses in 2020 in terms of revenues and volume of services (CNT, 2021; IBGE, 2021c; NTU, 2020). On the other hand, the transport of urban goods and merchandise is more resistant as there has been an increase in online shopping, such as the delivery of meals and food. However, the latest edition of the Brazilian survey shows that more than half of companies of the transport sector (53.4%) reported that it is not possible to predict when the losses in their company will end. Due to the restrictions on social mobility, the reduction in the country's economic activity and its linked effects on income and employment, the general picture shows that, in total, 68.3% of the carriers suffered a reduction in demand; 69.0% of sales; 57.4% of payment capacity; 49.0% acquisition of vehicles and equipment; 44.7% in the workforce; and 41.2% in the size of the company (CNT, 2021).

Some governments are providing short-term financial support in the form of subsidies, such as the United States, which announced a US$ 25 billion package in 2020 to help the public transport service (FTA, 2020), while London in the United Kingdom received 1,6 billion pounds (Flores Filho, 2021). In this context, the National Association of Urban Transport Companies (NTU) in Brazil has been discussing, since 2020, with transport specialists and the government the need for financial support policies. Federal assistance has been considered by the Emergency Social Transport Program (Legislative Decree No. 6, March 20, 2020) (Brasil, 2020a). This program provides a free supply of transportation cards to the lower income segments of the population, ensuring that the public bus service is not discontinued. For example, the city of Curitiba (PR) estimated a value of BRL 32.7 million for the Social Card Program. According to the January 3, 2021 edition of the NTU survey, among the measures adopted by the Brazilian government to reduce losses in public transport by bus, the most notable are subsidies, tax relief, and advance credit purchases electronics (NTU, 2020). The government of the most populous Brazilian city (São Paulo) has granted BRL 574.7 million in subsidies passed on to bus companies. Another measure that went into effect for 6 months was the suspension of payment of financing contracted through the Fleet Renewal Program for Public Urban Transport for Passengers (Refrota 17) to support public transport companies (Brasil, 2020b).

In other instances, without more specific actions by the Brazilian government to support the transport sector, companies relied on measures to suspend employment contracts and reduce wages (Law No. 14.020), adopted for the entire private sector (NTU, 2021). The emergency measure of temporary suspension of the employment contract with full payment of unemployment insurance prevents mass dismissal, whose labor costs are equivalent to 40–50% of the total (Carvalho and Pereira, 2012). In Brazil, the emergency employment and income maintenance program allowed the flexibilization of the labor market. Within the scope of emergency measures, a Special Emergency Regime for Urban and Metropolitan Public Transport was proposed to reduce the taxes levied on these services to protect the sector (Schiochet, 2020). Such a project established an emergency aid of BRL 4 billion to support public transport systems (i.e. buses, trains, and subways) for cities with more than 200 thousand inhabitants (NTU, 2021). This proposal was not implemented due to budget constraints by the Brazilian government.

Taxi drivers are also suffering from social distancing due to the reduced number of travels. As part of the emergency measures, the vehicle financing installments paid by these workers was suspended (Law No. 1721) (Almeida, 2020). Particularly for road cargo transportation, the emergency resource policy grants credit to truck drivers in support of expenses with maintenance, general services, and truck conservation (BNDES, 2020). As for the air transport sector, a provisional measure (No. 925) extended the deadline for the payment of fixed and variable contributions paid by airport companies without charging fines in 2020 (Brasil, 2020d) and a new provisional measure (No. 1024), in progress, extends the rules for refund and cancellation of airline tickets until October 31, 2021 (Brasil, 2020e). The main Brazilian airline companies, Gol, Azul, and LATAM, accepted financing terms from the National Bank for Economic and Social Development (BNDES) and private banks. The agreement states that each company would receive up to BRL 2 billion (Mandl et al., 2020). However, until October 2020 the proposal had not been implemented (Bouças et al., 2020). Until mid-May 2020, the BNDES was also negotiating with car manufacturers to provide financial assistance to the sector. The automakers suggest that tax and tax credits they have with states and federal government be used as a guarantee for financing, but the BNDES has considered that this suggestion poses a high risk for the bank (Kutney, 2020). In June 2020, the Brazilian government launched the program known as Guarantee Fund of Operations (GFO) for micro and small businesses and granted a credit amount of BRL 33.5 billion with a special interest rate for all sectors of the economy until the end of the same year. However, this credit resource was insufficient to mitigate the financial crisis of companies in the passenger transport sector in the country.

In common with the rest of the productive sectors, government financial support in the passenger transport is necessary to preserve income, employment, and activity during the pandemic and post-pandemic. In practice, this drops in demand for passenger transport caused by social distancing may, in the long run, represent a change in household preferences in demands for travel, with the replacement of other passenger transport services, and new habits. The United States, for example, has started testing the delivery of goods using electric cars. In China, with government support, electric robot vans were produced to transport medicines and food (Tanji and Vogel, 2020).

Even with several political proposals to help the sector, the future of continuity and survival of the providers of passenger transport services remains uncertain in the Brazilian economy. Even after the period of social isolation in the country, which may end in the end of 2021, it is uncertain and questionable whether urban mobility, business cycles, and the movement of people will be able to generate sufficient demand to accommodate the surplus supply of this type of services. In this variant, the Institute of Economics in Barcelona (IEB) analyzed the level of demand that public transport in Barcelona will be able to accommodate without causing saturation if the new distancing parameters are implemented (IEB, 2020). The various political measures proposed and forwarded to the Brazilian government can be central candidates in the recovery of transport services that promote public agglomerations in Brazil. To contribute to the debate in course on these policies, our paper analyzes the economic impacts of the COVID-19 outbreak on this group of sectors with public agglomerations and on the Brazilian economy, taking into account the redistributive effects on households, both in terms of income and the demand for public and private transport. Projected effects represent deviations from the Brazilian baseline forecast path (absence of COVID-19 outbreak) up to the end of 2022. Furthermore, as there is uncertainty about the recovery of the group of public agglomeration sectors during and after the outbreak of COVID-19, we considered two scenarios: (i) one that limits the recovery of demand in these sectors by 50% by the end of 2020 (6 months); and (ii) another that extends this

Table 1
Summary of research applied to infectious diseases using the CGE analysis.

Category	Analysis periodicity	Disease	Scope	Reference
Static National Model	Annual	SARS	Social and economic impacts of the disease on the tourism industry on the Thailand economy	Steinmueller (2005)
	Annual	Avian Influenza	Consequences of the disease in Taiwan's macroeconomics and individual industries	Chang et al. (2007)
	Annual	Influenza	Economic cost of a pandemic in the U.K., France, Belgium and The Netherlands	Keogh-Brown et al. (2008)
	Annual	Influenza	Provides the economy-wide impact considering vaccine efficacy, school closures and prophylactic absenteeism	Smith et al. (2009)
	Quarterly	Influenza	Economic effects of two influenza outbreak scenarios in the U. S. economy	Prager et al. (2017)
	Annual	Covid-19	Potential impact of Covid-19 on the United Kingdom economy	Keogh-Brown et al. (2020)
Dynamic National Model	Annual	SARS	Macro and microeconomics impact in an *ex-post* SARS assessment for Taiwan	Hsu et al. (2005)
	Quarterly	Influenza	Impacts of a hypothetical H1N1 outbreak by infecting about 90 million Americans	Dixon et al. (2010)
	Annual	Avian Influenza	Six scenarios to assess the likely effect of an avian flu outbreak in Ghana	Diao (2011)
	Annual	Ebola	Socioeconomic effects of the disease in Guinea, Liberia and Sierra Leone	UNDP (2014)
	Quarterly	Covid-19	Economic impacts of the pandemic at the national and industrial levels of the Chinese economy	Duan et al. (2020)
	Annual	Covid-19	Impacts of the Covid-19 pandemic in China's transport sectors	Cui et al. (2021)
Dynamic Global Model	Annual	SARS	Economic costs of the disease by focusing on the impacts on consumption and investment	Lee and McKibbin (2004)
	Annual	SARS	Economic implications of the 2003 SARS outbreak in China and Hong kong	McKibbin (2004)
	Annual	Influenza	Consequences of a pandemic outbreak on the global economy through a range of four scenarios	McKibben and Sidorenko (2006)
	Annual	Covid-19	Potential impact of coronavirus on gross domestic product and trade	Maliszewska et al. (2020)
	Annual	Covid-19	Three scenarios to assess the impact on the global economy of the disease with quantitative trade modelling	Bekkers et al. (2020)
Dynamic Multiregional Model	Annual	SARS	Economic effects of the pandemic in Australia's tourism industry and economy for 2003	Dwyer et al. (2006)
	Annual	Covid-19	Impacts of the pandemic on the Australian economy considering the grape and wine industry	Wittwer (2020)
Static Multiregional	Annual	Covid-19	Economic effects of the pandemic on the international tourism market	Pham et al. (2021)
Dynamic Interregional Model	Annual	Covid-19	Impacts of Covid-19 outbreak on the Brazilian economy	Porsse et al. (2020)
Dynamic Global Multiregional Model	Annual	Influenza	Potential cost to the global economy of an infectious disease outbreak	Keogh-Brown et al. (2008)
	Quarterly	Influenza	Economic effects considering a high virulence-low infectiousness and a low virulence-high infectiousness	Verikios et al. (2011)
	Annual	Ebola	Economic impact of the disease for West Africa and specific impacts for Liberia	Evans et al. (2014)
	Quarterly	Ebola	Economic effects which might have occurred if the disease had spread to developing countries	Geard et al. (2016)
	Quarterly Annual	Influenza	Economic effects of the pandemic and demonstrate the importance of quarterly periodicity	Verikios (2017)
	Annual	Covid-19	Macroeconomic impacts of mandatory business closures due to Covid-19 on the American economy	Walmsley et al. (2020)
Dynamic stochastic	Quarterly	Covid-19	Impact of the coronavirus outbreak on the tourism industry	Yang et al. (2020)
Hybrid DSGE/CGE Model	Annual	Covid-19	Potential global economic cost under seven different scenarios of the Covid-19 outbreak	McKibbin and Fernando (2020)

Source: Own elaboration.

50% sectorial recovery until June 2022. Both scenarios are different after June 2021, when vaccination in the country becomes more intense and that will influence the relaxation of social distancing measures. Each scenario considers an economic environment that included the loss of labor supply and productivity, public budget policies attenuating the outbreak, as well as the changing preferences of households in demand by durable, consumer goods and certain services. Thus, we project the economic environment in which public agglomeration transport services are inserted and how they respond to recovery times. The results of this type of analysis may show whether the activity variation in these sectors and its speed at which play an important role in deviating from the growth of the Brazilian GDP. The result may reinforce the importance of the effective implementation of the aforementioned policy proposals.

The analysis proceeds from a dynamic computable general equilibrium (CGE) model that incorporates flows of the Brazilian Social Accounting Matrix (SAM) in its theoretical and data structure, recognizing in detail the passenger land markets, such as subway, urban road transport, inter-city transport, air transport and associated services (e.g., airports). This is evidenced by the results of these activities, which were especially affected by measures that sought to reduce the spread of the disease. Moreover, the recursive dynamics module allowed us to apply shocks in different months of 2020 and to obtain periodical and accumulated results until the end of 2021. The CGE models are suitable to analyze systemic effects due to exogenous shocks, as in the case with the COVID-19 outbreak. The literature discussed in the next section presents several studies that used this methodology to assess the economic effects of other pandemics (e.g. SARS and avian flu) and also the COVID-19 pandemic (Chang et al., 2007; Keogh-Brown et al., 2008; McKibbin and Fernando, 2020). Other studies also have assessed the relationship between COVID-19 and the transportation sector (Bian et al., 2021; Cui et al., 2021; Gaskin et al., 2021; Hensher et al., 2021; Zhang, 2020), with impacts on travel behaviors and mobility commuting (Bohman et al., 2021; Hensher et al., 2021), and the impacts of COVID-19 on air transportation (Andreana et al., 2021; Zhu et al., 2021). The difference between the applied research described in the following section and in our study, in addition to the analytical scope, is the treatment given to the model's structure to consider the different types of households by income range, the possibility of income transfer between government and households and the different economic environments regarding the government's budget behavior.

In what follows, the next section presents the applied literature related to the assessment of the economic effects of pandemics. The third section describes the CGE model used to simulate the COVID-19 impact detailed in the fourth section. The fifth section summarizes the main results while the sixth section concludes and presents the policy implications.

2. Infectious diseases – a review of approaches

CGE models have been used to better understand the economic effects of some infectious diseases [e.g., Severe Acute Respiratory Syndrome (SARS), Ebola], including its short-term effects on the global economy [see Bekkers et al. (2020); McKibbin and Fernando (2020)]. Table 1 shows a summary of applied studies related to the economic effects of recent pandemics such as COVID-19 and SARS. In general, these effects include large reductions in the consumption of goods and services, such as air passenger transport, public transport and tourism-related activities, changes in household preferences in relation to exposed sectors, increases in operating costs for firms, impacts on global financial markets, and strong contraction of international trade. There are many channels through which an outbreak of a highly communicable infectious disease, such as COVID-19, affects the economy and, directly and indirectly, households, firms and governments. As the virus spread increases, given national and international travel flows, and governments impose measures to restrict the circulation of people to mitigate the spread of the disease, there are increases in mortality, speculation, uncertainties about what will happen first, the workload of health professionals, and the health expenses of patients and financiers (for example, governments and insurers). In addition, some workers may take (forced or voluntary) paid holidays and reduce the productivity of their company's work (e.g., reduction of production per worker), and some foreign investors may lose confidence.

Traditional cost estimation methods should yield more complex models, such as CGE models, to capture the consequences of a pandemic with the drop in labor supply, the closure of schools which leads parents to withdraw from work, the closure of service activities in general as a result of social distancing measures, and the increased demand for medical services. According to the United Nations Development Program (UNDP, 2014), CGE models have a more realistic view on how a pandemic affects the economy, since they consider the interaction among economic sectors. The CGE modeling is essentially a simultaneous equation system that involves thousands of equations and variables and can use economic data, such as Social Accounting Matrix (SAM), to simulate interactions between the economy and policy changes at the national level. For example, Smith et al. (2009) analyzed the economic impact of pandemic influenza associated with behavioral responses, school closures, and vaccination using a CGE model calibrated with a SAM for the United Kingdom. The authors found that the school closure and its related absenteeism contribute to increase economic loss in the country. The purpose of these studies is to understand the effects of infectious diseases spread on the demand for certain services. For example, the tourism and related industries (e.g., the aviation industry and land transport; restaurants and hotels; amusement parks and museums; small and medium-sized businesses) suffered losses from the SARS outbreak in 2003. Hsu et al. (2005) quantify these losses using a dynamic CGE model for Taiwan's economy. The sectors that suffered the most significant losses were air transport (−15.14%), travel agency services (−14.66%), hotel services (−13.78%), and consultancy (−12.74%). In his study, Steinmueller (2005) showed that tourism revenue in Thailand could have increased by 11% if the SARS outbreak had not occurred. The global costs of the 2003 SARS outbreak were significant and not limited to the countries directly affected (Lee and McKibbin, 2004). Other SARS studies include Australia (Dwyer et al., 2006), China, and Hong Kong (McKibbin, 2004).

CGE models have also been applied in several studies to assess the impact of the influenza pandemic (Dixon et al., 2010; Keogh-Brown et al., 2008; McKibben and Sidorenko, 2006; Prager et al., 2017; Smith et al., 2009; Verikios, 2017; Verikios et al., 2011). For example, McKibben and Sidorenko (2006) used the CGE modeling to produce four pandemic scenarios: mild, moderate, severe and ultra. The first scenario is similar to the Hong Kong flu (1968–1969); the second one is analogous to Asian flu (1957); and the severe and ultra-scenarios are based on the Spanish flu (1918–1919). The results showed an economic slowdown with costs between US$ 300 million and US$ 4.4 trillion depending on the scenario considered. A mild pandemic would cost 0.8% in terms of GDP, while global GDP would drop by up to 12% in a severe scenario. Keogh-Brown et al. (2008) have shown that negative impact on GDP would be 0.5% with losses for household consumption of up to 1%, with school closures contributing more to the projected reduction in GDP. The macroeconomic effects of an infectious disease outbreak are more sensitive on the demand side, such as declines in international tourism and leisure activities involving public meetings, than on the supply side, such as declines in productivity, as shown by Dixon et al. (2010).

In turn, Verikios et al. (2011) have used a modified version of the Global Trade Analysis Project (GTAP) model with dynamic mechanisms and quarterly frequency to assess influenza pandemic effects. The authors considered two scenarios: (1) high mortality and low infectivity; and (2) low mortality and high infectivity. The results showed that regions with greater economic integration into the world economy tend to be more affected by the pandemic. In a more recent study, Verikios (2017) has also analyzed the economic effects of pandemic flu to demonstrate the importance of quarterly frequency in assessing such developments, since these pandemics started and ended within a year. CGE modelling was also employed to analyze the economic consequences of the H5N1 avian influenza outbreak (e.g. Chang et al., 2007; Diao, 2011; Rodríguez et al., 2006).

Geard et al. (2016) examined the consequences if the West African Ebola epidemic in 2014 had been imported into some countries in the Asia Pacific using a quarterly version of the GTAP model. They found extremely high economic costs associated with uncontrolled Ebola outbreaks. Evans et al. (2014) modeled the economic effects of Ebola by distinguishing between a low and high epidemic scenario. The reduction in economic activity varied between 0.2% and 3.3%, respectively, in both scenarios. Other surveys applied CGE models such as UNDP (2014), also calibrated with a SAM, to examine the socioeconomic impacts of the Ebola in three countries: Guinea, Liberia, and Sierra Leone. The service of the three economies has been severely affected by the disease, which interrupted cross-border trade by raising the prices of food and other goods. Moreover, recent studies have implemented CGE models to understand the possible effects of COVID-19, which have been disrupting the Chinese economy since December 2019 and had spread rapidly to the Brazilian economy (Bekkers et al., 2020; Cui et al., 2021; Duan et al., 2020; Keogh-Brown et al., 2020; Maliszewska et al., 2020; McKibbin and Fernando, 2020; Pham et al., 2021; Porsse et al., 2020; Walmsley et al., 2020; Wittwer, 2020; Yang et al., 2020). The outbreak that began in the Chinese city of Wuhan in the province of Hubei quickly turned into an emerging public health crisis, prompting the World Health Organization (WHO) to declare it as a global pandemic on March 11, 2020. This statement led the WHO to coordinate international responses to the highly infectious disease. McKibbin and Fernando (2020) published one of the first economic cost studies for COVID-19 using CGE models. The authors used the modeling developed by Lee and McKibbin (2004), extended by McKibbin and Sidorenko (2006), exploring seven scenarios based on the survey of historical pandemics. The authors found that Brazil's GDP in 2020 would decrease by 0.3–8.0% and the number of deaths would have an estimation of 257,000 deaths.

The previous literature that analyzes the economic effects of past pandemics, such as SARS, has not taken into account a severe measure of social distancing. The social distancing affects the types and size of specific shocks to be performed in the CGE models [see Bekkers et al. (2020)]. Walmsley et al. (2020) estimated a fall of 20.3% of the United States' GDP annually in the three-month scenario of the mandatory closures. According to Yang et al. (2020), the COVID-19 outbreak hampers the tourism sector and health status, reducing the welfare of households. Pham et al. (2021) analyzed the economic damages caused by Covid-19 to the Australian tourism industry. In addition to the effects on the tourism sector, the authors found that the pandemic has also affected other industries and occupations. The vulnerability of the transport sectors due to the pandemic was also indicated by Cui et al. (2021). Using a multi-sectoral CGE model, the authors found that the outputs of freight transport sectors and passenger transport sectors in the Chinese economy would decrease by 1.03–2.85% and 3.08–11.44%, respectively. Bekkers et al. (2020) highlighted the global reduction in GDP ranging from 4.8% to 11.1%, depending on the scenario considered, while Maliszewska et al. (2020) projected a loss of 2.1% of global GDP, 2.5% in developing countries, and 1.9% in industrialized countries. For Brazil, these researchers estimate a reduction in GDP ranging from 4.8% to 11.6% for the year 2020. In common, these studies show how services can be negatively affected by isolation measures, including the effects on restaurants and hotels, tourism, transportation, entertainment, sports, and childcare services. Changes in demand for health services and government spending increase temporarily. There is a change in the consumption pattern of families with the greater use of specific services, such as delivery and streaming, in addition to the demand for products that previously did not have a large share in consumers' baskets. The loss of confidence of consumers and investors is a sign of the spread of the contagion of the disease with the worsening of the distribution of income and the increase in indebtedness, representing a major political challenge.

The study of past epidemics provides useful insights into the economic effects that include service sector exposure and the impact of social distancing. All these factors remain relevant today. Our study develops a dynamic computable general equilibrium model capable of analyzing the economic and short and long-term transport activities of the evolution of COVID-19 on a quarterly basis. Most CGE models use the annual periodicity, which is inappropriate for this type of study by smoothing out the short-term effects, as highlighted by Verikios et al. (2011). Similarly, we assessed the economic effects of COVID-19 in Brazil, with special attention to transport activities that potentially generate public agglomerations and a short-time scale (months). Like the recent applied studies, we have prepared a dynamic computational general equilibrium (CGE) model (Horridge, 2002), but also with a fiscal module and payment flow (Corong, 2014). These characteristics make it possible to apply more appropriately fiscal policies that mitigate the adverse effects of social isolation in force in the country. The option for a shorter periodic analysis in a dynamic modeling with the detailing of transport activities and in the theoretical structure prevents the analysis from being incomplete or distorted for the sectors of public agglomerations.

3. The CGE model

The CGE model applied in this study is an extension of the traditional ORANIGRD model (Horridge, 2002) by introducing a fiscal balance module and payment flow in its theoretical and data framework. This extension is fully derived from the PHILGEM model (Corong, 2014), a static model based on a social accounting matrix (SAM). SAM-based CGE models are able to establish links and interactions between expenditures and production in the economic system, as an input-output (I–O) analysis, but they also outline how income is generated, distributed and transferred between households (H), productive sectors (F), public administration (G) and rest of the world (RoW). Named as BIM (Brazilian Intersectoral Model), our model is a SAM-based CGE model with dynamic recursive, which includes rules of capital accumulation, investment allocation and wage adjustments with lag (Horridge, 2012), such as in the BIG-TP model (Proque, 2019) and BRIGHT model (Cardoso, 2016). Dynamic models allow for the analysis of a set of policies that have different temporalities, including monthly, quarterly and annual analyses. Such aspect contributes to an analysis of the time path of economic effects from three-month social isolation due to Covid-19 in 2021.

The BIM is also an upgraded version of the models previously developed by Betarelli Junior et al. (2020b, 2020a) and provides solutions in terms of percentage change (Johansen, 1960), based on a theoretical framework composed of simultaneous equation systems representing the supply and demand side of commodity and factor markets, as well as the mathematical identities of SAM's flows. The model's core database details the passenger and freight transport services in Brazil, including airport and port services. In general, these innovations contribute to analyze the economic effects on various transport services and macroeconomic environment in Brazil during the period of social isolation due to COVID-19, taking into account some fiscal policies of the Brazilian public budget. In our modeling, we disregard the imperfect substitution between certain transport services by assuming that this type of optimizing behavior does not exist in an atypical economic environment such as the COVID-19 crisis.[1]

Compliant with a standard CGE structure, producers and investors minimize costs for the production level, and household maximizes utility through separate processes in a nested structure (Dixon et al., 1982). Industries produce single commodity(Z_i) requiring intermediate inputs composites (X_i) and added value composites (V_i) in fixed proportions:

$$Z_i = \min(X_i, V_i) \tag{1}$$

Each composite is derived from a constant elasticity of substitution (CES) function. Consequently, changes in the relative prices of inputs induce imperfect substitution in favor of relatively cheapening inputs inside the composite (Armington, 1969). Within intermediate input composites, this substitution effect occurs between domestic (D_i) and imported (M_i) sources, while in value added the substitution is between land (R_i), capital (K_i) and labor (L_i):

$$X_i = \left[\sum_{i=1}^{s} \delta_{s,i} X_{s,i}^{-\rho^X}\right]^{\frac{-1}{\rho^X}} \forall\, s = (D, I) \tag{2}$$

$$V_i = \left[\sum_{i=1}^{f} \delta_{f,i} V_{f,i}^{-\rho^V}\right]^{\frac{-1}{\rho^V}} \forall\, f = (L, R, K) \tag{3}$$

where δ is a participation parameter that satisfies$\sum_{i=1}^{f}\delta_{f,i} = 1$ or $\sum_{i=1}^{s}\delta_{s,i} = 1$, while ρ corresponds the substitution elasticities, which vary among industries and inputs. This nested structure of two-level production is similar for investment demand in our model, that is, investors (I_i) combine inputs that minimize costs to create capital, but they do not directly use primary factors as inputs (eq. (3) does not exist in capital production). There is a link between investment and capital according to the dynamic mechanism of capital accumulation in each period $t + 1$(Horridge, 2012):

$$K_{i,t+1} = (1 - \phi_i)K_{i,t} + I_{i,t} \tag{4}$$

where $K_{i,t}$ is the quantity of capital stock available to sector i in period t, and ϕ_i is the rate of depreciation (constant over time). The base year quantity of capital stock is provided exogenously, and the calculation and calibration procedures are described in Betarelli Junior et al. (2020b). Additionally, according to Horridge (2012), investment allocation is defined by two basic rules (Chen, 2019):

[1] Intermodal substitution is recurrent and has increased in the applied literature such as Betarelli Junior et al. (2020a), Schäfer and Jacoby (2005), Bruvoll and Larsen (2004), Steininger et al. (2007) and Bröcker and Mercenier (2011).

$$G_i = \frac{I_{i,t}}{K_{i,t}} = F(E_i) \quad (5)$$

$$G_i = Q_i \cdot G_i^{Tend} \cdot \frac{(M_i)^{\xi_i}}{Q_i - 1 + (M_i)^{\xi_i}} \quad (6)$$

where in eq. (5), the investment/capital ratios or gross rate of capital growth in the next period are positively related to the expected rates of return (E_i); and in eq. (6), the expected rates of return converge to actual rates of return via a partial adjustment mechanism (Chen, 2019), with $M_i = E_i/R_i^{Normal}$, such that $R_{j,i}^{Normal}$ is the normal rate of return of capital for investor i; G_i^{Tend} is the growth trend of capital stocks, $Q_{j,i}$ is the (max/trend) investment/capital ratio; and ξ_i denotes the investment elasticity.

In our model, each household h maximizes utility subject to a budget constraint. The utility is derived from a Klein-Rubin function, non-homothetic or quasi-homothetic, which separates a fixed portion of subsistence spending and a residual portion of "luxury spending". The demand for luxury goods varies according to prices and income, affecting the consumers' utility; and households also choose rationally between domestic and imported goods (CES function). The model considers the hypothesis of a small economy in the Brazilian foreign trade, but the export demand is a negative function of the price in relation to the exchange rate. Inventory variations follow the behavior of sectorial production and in the labor market the wages increase if the current employment is above the trend employment, and vice versa. The growth of real wages in the current period negatively affects current employment, which periodically reduces until it converges with its trend level (Horridge, 2012). A public budget identity is included, which can establish the hypothesis of a balanced budget by linking the expenditures with the taxes and income of the government. The remainder of this section focuses on this issue.

3.1. Fiscal module and payment flow (SAM)

The SAM structure is an expanded version of the input-output table and comprises additional accounts of transactions and transfers among economic institutions in a system, such as productive sectors (F), households (H), public administration (G) and the rest of the world (RoW). This type of data framework for our CGE model reveals the circular flow of income and expenditure in an economy, that is, it outlines the origin, distribution and allocation of income among economic agents for different uses (Miller and Blair, 2009). Table 2 illustrates a stylized SAM structure in general balance, whose separate accounts are scaled by indexes. As in an I–O analysis, the first row and column denote the distribution of sales and costs of the production of each sector i, so that total demand (D_j) is equal to the total output (Z_i):

$$D_i = \sum_{i=1}^{n} X_{ii} + X_{i,H} + X_{i,G} + X_{i,I} + X_{i,E} = Z_i = \sum_{i=1}^{n} X_{ii} + M_i + V_i + T_i \quad (7)$$

where X_{ii} is the use of intermediate inputs i by sector i; and $X_{i,H}+X_{i,G}+X_{i,I}+X_{i,E}$ represent the final demand matrix for the good i, composed of household ($X_{i,H}$), government ($X_{i,G}$), investment ($X_{i,I}$)and export ($X_{i,E}$). On the right side of eq. (7), we have the sum of the production costs of the sector i, as intermediate inputs($\sum_{i=1}^{n} X_{ii}$), imports (M_i),taxes (T_i) – commodity tax and production tax – and value added (V_i), formed by labor (L_i), land (R_i) and capital (K_i). Hence, the pre-tax GDP (Gross domestic product) is:

$$\sum_{i=1}^{n} (X_{i,H} + X_{i,G} + X_{i,I} + X_{i,E} - M_i) = GDP_i = \sum_{i=1}^{n} V_i = L + R + K \quad (8)$$

In the same way, we can extract other mathematical identities in this SAM structure, especially between the total received (income) and the total (payments) of each economic agent. For example, the total government income (Y_G) represents revenue tax (T), transfers received from economic institutions ($Tr_{G,j}$), including transfers received from the rest of the world ($Tr_{G,E}$); and the remuneration of capital (K_G): This public income (Y_G) is equal to total government cost (C_G), which denotes the sum of the total demand for domestic goods $\left(\sum_{i=1} X_{i,G}\right)$, imports ($M_G$), commodity tax ($T_G$)and total transfers paid, typically for households ($Tr_{H,G}$), firms ($Tr_{F,G}$)and other public institutions ($Tr_{G,G}$),in addition to the public savings portion (S_G), that is:

$$Y_G = K_G + T + \left(\sum_{j=1} Tr_{G,j}\right) + Tr_{G,E} = C_G = G + S_G \quad \forall j = (H, F, G) \quad (9)$$

where$G = \left[\left(\sum_{i=1} X_{i,G}\right) + M_G + T_G + \left(\sum_{j=1} Tr_{j,G}\right)\right]$. Thus, public savings ($S_G$) are defined as:

$$S_G = Y_G - G \quad (10)$$

We can assume the hypothesis of a balanced budget or the hypothesis of surplus or deficit behavior of the government. In the first case, the variation in total expenditure $\left(M_G + \sum_{i=1} X_{i,G}\right)$is linked to aggregate tax revenue(T), formed by commodity tax, production tax and direct tax, while the second case does not have this link between expenditure and revenue in the public budget. Due to the critical economic situation generated by COVID-19 and reactive measures of the Brazilian public budget policies, we assume the hypothesis of free budget behavior (the second case).

Equations (9) and (10) can be similarly derived for households and firms with $Y_H = C_H$ and $Y_F = C_F$, respectively. In the case of the rest of the world (RoW), $M = C_E$, that is, current transaction abroad involving the capital transfers received (M) and sent (C_E). Thus, we have the traditional macroeconomic identity in the private and public sectors, plus the income and expenditure of the rest of the world (S_E), and total investment:

$$I = S = S_G + (S_H + S_F) + S_E \quad (11)$$

The above identities are derived from the SAM structure and incorporated into the BIM model, which presents a fiscal module and includes public savings, tax revenue and fiscal deficit, as well as private savings and disposable income, defined by the difference in income and taxes paid by each economic agent. There are also five types of typical households according to the minimum wage range. Therefore, the model used in this study is closer to the public finance practices in Brazil during the COVID-19 period, which includes a deficit behavior when intensifying health spending and providing emergency resources to Brazilian households with up to 3 minimum wages. These modeling features can provide or generate more accurate projections of simulation analysis.

3.2. Data

The BIM core database is derived from the System of National Accounts (SNA) of the Brazilian Institute of Geography and Statistics (IBGE) for the year 2010 (IBGE, 2019). It serves as the benchmark data for a CGE calibration. Originally, this database had 127 commodities and 67 economic sectors, but some transport services were disaggregated according to the data on the supply and demand structure at market prices required directly from IBGE's "System on National Account", as well as the compilation of detailed information on cargo flow and tariffs for ports, railway concessionaires and air cargo transport, obtained by the National Agency of Waterborne Transportation (ANTAQ), the National Agency of Land Transport (ANTT), the National Civil Aviation Agency (ANAC), the Secretariat of Ports of the Presidency of the Republic (SEP/PR) and the Ministry of Industry, Foreign Trade and Services (MDIC). After this disaggregation, the model database

Table 2
SAM structure.

		Production	Added value			Tax	Institution			Capital formation	RoW	Total received
		1 … i … N	L	R	K	T	F	H= (1 … h)	G	I	E	
Production	1 … i … N	$X_{i,i}$						$X_{i,H}$	$X_{i,G}$	$X_{i,I}$	$X_{i,E}$	$D_{i\cdot}$
Added value	L	$L_{\cdot i}$									L_E	L
	R	$R_{\cdot i}$										R
	K	$K_{\cdot i}$										K
Tax	T	$T_{\cdot i}$						T_H	T_G	T_I	T_E	T
Institution	F		L_F		K_F		$Tr_{F,F}$	$Tr_{F,H}$	$Tr_{F,G}$		$Tr_{F,E}$	Y_F
	H= (1 … h)		L_H	R_H	K_H		$Tr_{H,F}$	$Tr_{H,H}$	$Tr_{H,G}$		$Tr_{H,E}$	Y_H
	G				K_G	T	$Tr_{G,F}$	$Tr_{G,H}$	$Tr_{G,G}$		$Tr_{G,E}$	Y_G
Capital formation	S						S_F	S_H	S_G		S_E	S
RoW	M		L_M				M_F	M_H	M_G	M_I		M
Total paid		$Z_{\cdot i}$	L	R	K	T	C_F	C_H	C_G	I	C_E	

Source: Own elaboration.

recognizes 137 products, detailing especially the transport services (Betarelli Junior et al., 2020a; Proque, 2019). We use the data from the 2008 and 2009 Consumer Expenditure Survey (POF) to disaggregate household expenditure and income into 5 types of minimum wage range (IBGE, 2010), as shown in Table 3.

Thus, according to the model's data, in 2010, the transport services accounted for 4.71% of the national output, and 41.9% of the provision of this type of services came from the road freight transport. The transport service sells about 25.4% of its output to households and 68.5% to intermediate consumption. Brazilian households absorb more than 90% of the supply of subway, metropolitan passenger road and intercity and interstate and international passenger roads, and 58% of the supply of school transport, taxi and chartered. In turn, air passenger transport is mostly required by other sector activities, to allow for the travel of employees and businesses (74.24% of total demand). Households with income of 7 minimum wages (mw) or more concentrate 18.90% of the total demand for air passenger transport in Brazil, that is, increasing income represents a greater demand and willingness to pay for air transport service. Brazilian families do not demand air freight transport.

The analytical scope of this paper will focus on the projections for transport services reported in Table 3. However, some of these services are offered by a single productive sector (multiproduction) in the resource table of the IBGE's SNA. Consequently, a demand reduction shock for one of these services, such as that occurred during the COVID-19 outbreak period, would imply a generalized reduction in corresponding sectoral activity, leading to a distortion in the results of the analysis. To avoid this problem, the database of the BIM model was diagonalized so that each commodity is the industry itself. Traditionally, this transformation uses industrial participation in the production of each commodity as a reference. The concept of activity that produces a specific product includes the composition of sectoral technologies that are distinct from all sectors that produce the specific product. Thus, our model has 137 commodities/sectors, three primary factors (i.e., labor, land, capital), 137 investors, five household types, government, foreign consumer and inventories. We calibrated the model's data structure according to the distinct investment allocation behaviour in Miguez and Freitas' (2019) capital flow matrix (CFM). Our modeling also recognizes four margins, divided between one retail trade and three freight transport services (waterway, road and rail). Thus, the costs of the margins and indirect taxes are included in purchasers' prices but not in the basic prices of goods and services.

The behavioral parameters were calibrated according to Betarelli Junior et al. (2020b, 2020a). For example, the Armington elasticities were calibrated according to Tourinho et al. (2007), while the Frisch parameter was calibrated according to Almeida (2011). The spending elasticities were obtained from Hoffmann (2010). In the dynamic module of capital accumulation, we assume a steady state of 2%, a ratio of physical investments relative to the physical capital stock of 8.5%, which results in a depreciation rate of almost 6%.

4. Economic environment

4.1. Baseline

Dynamic recursive CGE models provide sequential solutions over a pre-established time interval. For each period, the solution loads the history of the previous periods, in addition to the shocks or changes in the current period. These solutions can be completely or partially monthly, quarterly, semi-annually or annually. We combined annual, monthly and quarterly solutions up to the end of 2022. The solutions are monthly for the years 2021 e quarterly 2022, to find out the turning point of the time path of economic variables.

In simulation analysis with dynamic models, there are two main types of closure, known as the economic environment, which defines the exogenous variables (Dixon and Rimmer, 2002). The first one is the baseline closure and, in this closure, we usually make the main macroeconomic variables exogenous, such as real GDP, investment, household consumption, government demands, export volume and aggregate employment. This is necessary to accommodate observed and prospective variations in periodic baseline solutions. Operationally, these macro variables are swapped for corresponding variables (e.g. shift in final demand, national wage and national TFP) to make them exogenous at baseline closure. After that, we applied the historical and prospective shocks to the main macroeconomic variables in this baseline, as described in Table 4.

Between 2011 and 2020, the observed changes are applied according to the statistical information of the IBGE's system of quarterly national accounts (SQNA) (IBGE, 2021a). For the same annual interval, variations in import prices follow the real effective exchange rate of imports from the Institute for Applied Economic Research (IPEA, 2020). The use of this historical data is aimed at updating the numerical structure of the model for the year of implementation of shocks under the Covid-19 scenario in Brazil. Moreover, trend employment follows the steady state of the Brazilian economy; and national employment and population in each current period vary according to the SNA data (IBGE, 2019). On the other hand, prospective changes after 2020 come from the forecast of the Federal Development Strategy for Brazil (Brasil, 2020c). Thus, the tendency of the economy, based on historical and prospective simulations, is traced basically considering hypotheses about the behavior of the main macroeconomic aggregates. In general, the

Table 3
Sector demand and supply in the model database.

Domestic sector activities	Share (%) of total demand								Total demand (R$ billion)	National output (share %)
	Intermediate consumption (X)	Households demand (mw)					Export	Other final users		
		up to 3	4–6	7–10	11–20	over 20				
Transport services	68,59	3,97	6,15	5,20	4,92	5,15	4,93	1,08	310,99	4,71
Rail freight	99,64	0,07	0,07	0,04	0,03	0,02	0,11	0,01	7,20	0,11
Road freight	91,46	0,72	1,07	0,96	1,08	1,25	0,88	2,57	130,31	1,97
Pipeline	100,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,94	0,07
Subway	9,64	10,09	20,29	21,09	20,29	18,20	0,40	0,00	1,76	0,03
Metropolitan passenger road	2,58	19,06	32,58	24,57	15,33	5,84	0,04	0,00	30,01	0,45
Transport school, taxi and chartered	42,00	13,04	12,36	10,27	10,73	11,61	0,00	0,00	16,19	0,25
Intercity, interstate and international passenger road	3,79	21,38	29,97	19,79	14,96	8,49	1,63	0,00	13,63	0,21
Water transport	52,92	0,65	0,96	0,90	0,97	2,05	41,49	0,07	14,62	0,22
Air freight transport	31,75	0,00	0,00	0,00	0,00	0,00	68,25	0,00	3,46	0,05
Air passenger transport	74,24	0,58	0,79	1,83	4,43	12,64	5,49	0,00	21,17	0,32
Cargo handling and storage	75,41	0,30	1,56	3,00	5,51	9,04	5,18	0,00	11,71	0,18
Auxiliary activities for land transport	62,16	0,57	3,01	5,72	10,53	17,31	0,71	0,00	19,27	0,29
Ports	66,13	0,08	0,40	0,77	1,41	2,32	28,90	0,00	8,85	0,13
Airports	60,00	0,39	2,15	4,08	7,48	12,37	13,51	0,00	4,56	0,07
Activities that organize cargo transport	75,40	0,30	1,57	2,99	5,52	9,06	5,17	0,00	8,07	0,12
Courier and other delivery services	90,05	0,51	1,13	2,28	3,28	2,70	0,05	0,00	15,23	0,23
Other products	39,76	3,75	5,94	5,65	6,86	8,03	6,47	23,54	6288,75	95,29
Total	41,12	3,76	5,95	5,63	6,77	7,89	6,40	22,48	6599,73	100,00

Source: CGE database.
Note: The household are divided as minimum wage ranges (mw).

Brazilian economy showed positive indicators until 2013. From 2014 onwards, a downward trend started, mainly in GDP and investment. Exports had a greater positive variation in the period after 2014. This recessive scenario ends in 2016 and the Brazilian GDP started to show a growth rate in the period 2017–2019, mainly due to the expansion of the domestic market. However, with the global crisis generated by the Covid-19 outbreak, the Brazilian economy experienced a sharp retraction (−4.06%) in 2020. All demand components exhibited negative real variations in the same year, but the decrease in household demand was the strongest (−5.45%), contributing to the shrinking of the internal markets (IBGE, 2021a). As a result, the labor force participation rate dropped by 7.9% in 2020. The total hours usually worked in all occupations, which corresponds to the product of the average workday by the number of employed persons, decreased by 0.51 in the same period, whose negative variation includes reductions due to illness, holidays, voluntary absences, delay or for any other reason, as well as increases due to peak production and compensation for hours not worked in another period. As occupations encompass the formal and informal market, the year 2020 affected informal workers in the country, less educated and less productive (IBGE, 2021e). The total factor productivity (PTF), which takes into account not only the productivity of the labor force, but also the efficiency of the use of capital, presented an accumulated reduction of 1.32% between the first and the last quarter of 2020 (Bonelli, 2021).

The second type of closure is policy closure. In this closure, the main macroeconomic variables are assumed to be endogenous (e.g. GDP), and the variables to be used as policy are assumed to be exogenous (e.g. term of productivity). The next section describes the economic environment for policy simulations.

4.2. Covid-19 scenario for Brazil

Our policy analysis is based on a scenario designed for the consequences of Covid-19 on the Brazilian economy from January 2021. The policy closure defines a scenario in which social isolation measures persist mainly between the end of January and June 2021 in the country, because Brazilian cities have decreed the temporary closure of local activities to contain the expansion of cases, hospitalizations, and deaths by Covid. The protocols were defined by "red and purple waves". In the municipalities that declare the red wave, activities considered non-essential were allowed, as long as they comply with some rules, such as distance and more restricted occupation within the establishment. This measure, however, is optional for each municipality, which can manage the resumption of trade in its own way. On the other hand, the purple wave protocols allow, in general, only the functioning of essential services, seek to contain any public agglomerations and stimulate the horizontal lockdown. Between March and May 2021, the purple wave protocols have been frequent due to the low rate of vaccination in the country. Up to mid-May 2021, the total number of people vaccinated by the first dose in the country reached 18.23% of the Brazilian population, which is equivalent to 38.5 million vaccinees (G1, 2021). Thus, we assume that the period between January and June 2021 may have new purple wave protocols with more intense economic adversity in view of the evolution of the vaccination rate in the country. Strong measures of the social distance of the purple wave are not expected in any other time interval.

We do not assume different formats of hypothetical curves (V, U and L), as in Challet et al. (2009) and Bekkers et al. (2020). There are two basic reasons for that. Firstly, we let the prospective projections time path respond endogenously to the scenario elaborated with 6-month social distance measures but taking into account hysteresis in the labor market and fiscal policies effectively applied to mitigate the economic crisis in 2021. Second, the time path of economic variables also depends on other political proposals that are being discussed by the Brazilian government and when they will be implemented, as well as on the reaction of the private sector in relation to the business cycle during and after the period of social isolation in the economy. These factors can determine the degree of recovery of the post-isolation Brazilian economy, which will define the formats of the Brazilian GDP trajectory for the coming periods.

According to McKibbin and Fernando (2020), there are many assumptions in this exercise, and the results are sensitive to these assumptions. Given these initial observations, our scenario will provide

Table 4
Shocks to the baseline closure, in real variations (%).

Indicators	Historical										Prospective		
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021		2022
											monthly	in year	in year
GDP	3,97	1,92	3,00	0,50	−3,55	−3,28	1,32	1,32	1,14	−4,06	0,165	2,00	2,00
Household demands	4,82	3,50	3,47	2,25	−3,22	−3,84	1,98	2,05	1,84	−5,45	0,165	2,00	2,00
Government demands	2,20	2,28	1,51	0,81	−1,44	0,21	−0,67	0,36	−0,44	−4,68	0,058	0,70	0,70
Exports	4,81	0,71	1,83	−1,57	6,82	0,86	4,91	4,00	−2,54	−1,76	0,168	2,03	2,03
Investment	6,98	0,78	5,86	−4,02	−14,35	−12,42	−2,56	3,91	−0,44	−0,78	0,146	1,70	1,70
Current employment	1,47	1,41	1,56	2,86	−3,34	−1,56	1,25	1,20	1,20	−7,94	0,165	2,00	2,00
Trend employment	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	0,165	2,00	2,00
Population	0,88	0,87	0,85	0,86	0,87	0,83	0,80	0,85	0,85	1,00	0,083	1,00	1,00
Import price index	1,79	1,59	2,45	7,84	−4,72	−0,83	4,11	−6,84	−1,44	–	–	–	–

Source: IBGE (2019, 2020) and forecast of the Federal Development Strategy for Brazil (Brasil, 2020d).

economic deviations of the Covid-19 outbreak from the Brazilian baseline projection path up to 2022, free from new political measures or new events that may affect the trajectory of economic variables. Based on some studies, as Challet et al. (2009), Bekkers et al. (2020) and McKibbin and Fernando (2020), we elaborated three types of scenarios according to Fig. 1. The first scenario consists of three axes and we will denominate as "common" because it will be common for other scenarios that deal with the recovery of certain transport services in public agglomerations, defined as: (2) recovery in 2021 and (3) recovery in 2022. Each recovery scenario considers the shocks expected in the common scenario. The purpose of this simulation design is to assess the role of the recovery of certain transport services for the Brazilian economy within a common scenario of COVID-19 outbreak.

In this common scenario, the first axis of simulation denotes the labor market (i). In the labor market, we assume a fall in the labor supply of up to 0.60% in June 2021, due to the lethality rates, the implicit mortality rates, inflection rates and the unemployment created initially by the paralysis of some sectorial activities because the social distance caused by the outbreak in Brazil. Until June 2021 we assumed the vaccination rate in the country is still not enough to avoid purple wave decrees. Moreover, This accumulated rate of 60% until June 2021 took as a reference the accumulated decrease of 0.51% of the Average hours usually worked per week in the main job of persons aged 14 years and over (hours) in 2020, according to statistics from the IBGE (2021e). With a greater coverage of the vaccination rate after June 2021, a marginal growth of the average hours worked in the country is expected, which would reach an accumulated reduction of 0.50% by the end of the same year. Table 5 shows the distribution of shock values between 2021 and 2022. This negative impact on employment is considered moderate given the three scenarios developed by Bekkers et al. (2020). With this restriction, the recovery of the labor market may occur endogenously from 2022, reflecting certain hysteresis in the labor market. The trajectory of the negative job supply shock follows a convex function (Appendix A, panel a). Moreover, due to the change on the capital−labor ratio in view of the possible effects caused by morbidity and mortality, school closure[2] and working at home (home office), this pandemic crisis negatively affects labor productivity, which continues until the end of 2021. We assume that this reduction accumulates more intensely until June 2021, reaching a conservative rate of −1.50%, as discussed by Bekkers et al. (2020). This shock had reference to the accumulated reduction of 1.62% in PTF of effective hours worked between the first and last quarter of 2020 (Bonelli, 2021). The trajectory of reduced productivity is similar to that of employment (Appendix A, panel b).

For the labor market, we also assume a drop in productivity. The intuition underlying the fall in labor productivity due to home office is basically related to changes in the work environment caused by an exogenous and immediate factor. Firms implement collective vacations or influence their workers to take paid vacations, which contributes to decrease the productivity of work in the enterprise until June 2021. An unscheduled change in the work environment may have a greater potential for loss of concentration and focus on work, such as adaptation costs. The lack of interaction with other professionals can also reduce the scale at the end of work, the effects of complementarity when working in groups and creativity. Hill et al. (2003) compared the effect of three different work environments on motivation, performance and career opportunities and concluded that each environment contributes differently to these aspects. Other applied research has found positive effects of the home office on productivity (Bloom et al., 2015; Neufeld and Fang, 2005), but under certain conditions. On the other hand, Bloom (2020) pointed that negative effects will be prevalent on labor productivity in 2020 because of the outbreak of Covid-19. For this reason, we expect the cumulative reduction in labor productivity in 2021 to be less than that of 2022 in Brazil. This scenario is expected, since in the years following the pandemic, the accumulated variation in productivity in the quarter in relation to the quarter of the previous year was 1% on average (Bonelli, 2021).

The uncertainty and risk of loss of income and jobs during the pandemic crisis make families postpone or suspend the demand for durable, consumer and other goods considered superfluous, that is, families start spending only on essential products in their consumption basket. Even after the period of social isolation, this change in family preference will last for some time (axis ii). For the same reason, households reduce the demand for personal, domestic, hotel, food and other types of services that can potentially generate social agglomerations (e.g. less people will go shopping, and cultural activities and events are temporarily cancelled). As people's behavior change in relation to purchases of goods and services, we assume that negative shocks represent changes in household preferences. In 2020, the volume of sales of services provided to families registered an accumulated drop of 28% (IBGE, 2021c). On the other hand, the physical production of durable consumer goods decreased by 4.87% in February 2021 (IBGE, 2021b).

Based on these statistics in Brazil and the scenarios prepared by Bekkers et al. (2020) and McKibbin and Fernando (2020), we assume a scenario in which household demand for certain goods and services will have decreased by 30% between January and June 2021. Again, we let the CGE model endogenously provide the projections after the period of greatest social distance (end of June 2021). On the other hand, it is expected that household demand for agricultural goods, processed foods and other necessary goods will increase in the same period, whose adjustment to the consumption basket will be captured endogenously by the CGE model. Demand for trade also declines, but this drop is milder. In the period of social isolation, people can shop online, by e-commerce or in open commercial establishments, the reduction being as shown by Bekkers et al. (2020). Bekkers et al. (2020) used a trade-to-GDP elasticity to project these negative effects in spending on durable goods that are highly tradable. In three-month isolation (2020), the authors define 80%

[2] School closure may imply that at least one parent would have to stay at home to take care of their children.

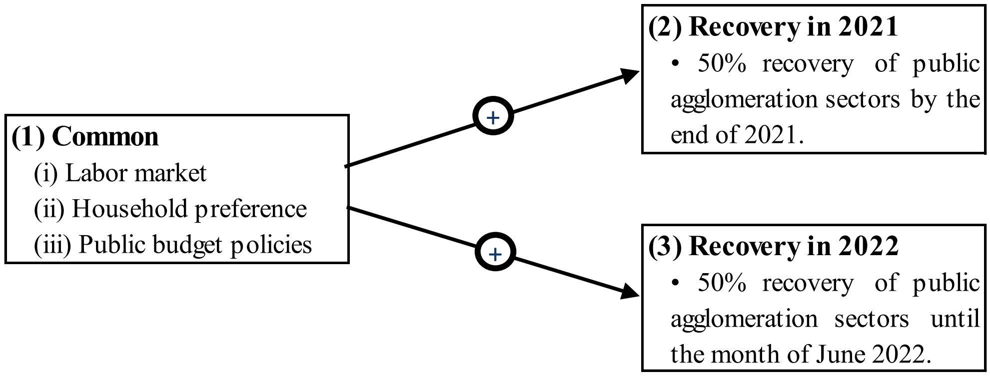

Fig. 1. Simulation design for political analysis. Source: Own elaboration.

reductions in the supply of and demand for these goods and services, with the exception for retail. In this case, the reduction should affect less the total supply of these products.

In our common scenario, there is also the public budget axis (iii), which encompasses two policies to mitigate the Covid-19 outbreak. In the previous experience of pandemics, governments around the world have adopted expenditure increase measures to prevent the pandemic outbreak or spread, such as strengthening health screening in ports and expanding the capacity of the health system, whether for the purchase of materials and equipment or for the expansion of health facilities and infrastructure (McKibbin and Fernando, 2020). We apply the Federal Government's budget amounts and expenditure for up to April 2021 (Brasil, 2021b). The total expenditure is BRL 40.6 billion and about 73.4% of this amount is intended for the health sector. The shock calculation takes as reference the government expenditure vector of the model database with the recursive update of the baseline until January 2021. Then, we distribute these percentage shocks evenly in each month of 2021, with the hypothesis of deficit behavior (i.e. free budget behavior, as presented in section 4.1). Under this same hypothesis, we also apply emergency aid in the amounts of BRL 600.00 or BRL 1200.00 for informal workers and for the low-income population (up to three minimum wages). This emergency package was approved by the so-called "war budget". According to more recent data from the Brazilian government (Brasil, 2020d), the action of this emergency measure was updated to BRL 293.38 billion and should cover approximately 70 million Brazilians. As it is the government's official information, we will use this amount as a reference for the shock in the scenario. These emergency resources began to be distributed to the Brazilian population between April 2020 and April 2021, but the shock considers only the restraints of the year 2021. At policy closure, this emergency amount is simulated as an addition to nominal government transfers to households with up to three minimum wages (mw). As the model recognizes transfers between the main economic institutions, we compute the individual shocks considering the database recursively updated for January 2021 (baseline), whose procedure is similar to that of government spending. Moreover, government transfers received by households are treated as constant in subsequent periods because there is no possibility or news of the Brazilian government reducing it according to the drop in tax revenue of the public budget in the face of the economic crisis.

Due to containment measures and uncertainties in the period of social isolation during this pandemic crisis, the supply of and demand for certain transport services are affected (Bekkers et al., 2020; McKibbin and Fernando, 2020). The restriction on the movement of people affects the demand for private, public and air transport, especially to contain social disturbances and prevent the contagion and transmission of the virus. To avoid the contagion and transmission of the virus, the guidelines of several health institutions are to avoid the use of transport services that promote public agglomerations. This sectorial category includes activities such as subway, metropolitan road, intercity, interstate and international passenger road and passenger air transport. Thus, we will call this category of transport services as "sectors of public agglomerations" for convenience and simplicity. Most of these activities are typically demanded by Brazilian households (i.e. more than 90% of total demand, Table 3). The exception is air passenger transport, which is also demanded for business trips (about 74% of total demand, Table 3). Hence, we applied a direct shock to the supply of this type of service, otherwise, the negative effect would be undervalued.

In Brazil, there is a movement to relax social isolation measures, even in a critical moment of the outbreak, with an increasing number of infected people and deaths, notably underreported by the lack of hospital equipment, facilities and massive testing of the population. Between March and December 2020, the reduction in human mobility in places such as public transport terminals went from 58% to 32% (Google, 2021). It is a percentage below the most affected European and Latin American countries, such as Argentina (−38%), France (−44%), Italy (−62%), Mexico (−39%), Spain (−44%), and United Kingdom (−67%) (Google, 2021). The 32% drop in urban mobility converges with the retraction in the volume of sales of Brazilian air transport at the end of 2020 (−31.9%), according to IBGE (2021c). In December 2020, the average reduction observed was 39.1% of trips made by passengers on public transport by bus (NTU, 2020). With the drop in passenger demand and the reduction in revenues, urban public transport had accumulated losses of BRL 11.75 billion in the period from March 2020 to February 2021 (NTU, 2021). The impacts on the sector are even greater when looking at bankruptcy and employment. The latest edition of the Brazilian survey, carried out by the National Transport Confederation, shows that 86.7% of the companies of the road passenger transport sector believe they will close the year 2021 at a loss (CNT, 2021). For these reasons, we simulate a common scenario that the fall in the activity of transport services associated with public agglomerations will reduce by up to 40% in June 2021. For these reasons, we simulate a common scenario that the fall in the activity of transport services associated with public agglomerations will reduce by up to 40% in June 2021. This is because these activities have already shown a 32% retraction at the end of 2020 and until June 2021 the restrictions imposed for the social distance from the purple wave must occur due to the slow speed of vaccination in the country.

To assess the relative importance of these sectors of public agglomerations, we have established two recovery scenarios with different time transition after the period of social isolation. The first one, (2) recovery in 2021, considers the common scenario and represents a more optimistic scenario, as well as establishes that there will be an exponential recovery of 50% by the end of 2021 (from July to December 2020), reaching an accumulated variation of −20% (Appendix A, panel c). This percentage variation seems reasonable, since some activities such as universities, schools and other sectors remained paralyzed, negatively affecting the demand for subways, buses and flights. In turn, the third scenario, recognized as "(3) recovery in 2022", points to a slower recovery in the sectors of public agglomerations, that is, it establishes a 50% recovery in these economic activities, reaching an accumulated

Table 5
–Shocks under the Covid-19 outbreak in Brazil (% cumulative variation).

Scenarios	2021						2022
	jan.	apr.	jun.	… *up to* …	dec.	… *up to* …	jun.
(1) Common							
(i) Labor market							
• Labor supply	−0,56	−0,59	−0,60		−0,50		–
• Labor productivity	−1,41	−1,48	−1,50		−1,00		c
(ii) Household preference (tastes)							
• Durable, consumer and other goods, except food and agribusiness	−0,23	−9,96	−30,00		–		–
• Freight transport service, except post office	−0,23	−9,96	−30,00		–		–
• Personal, domestic, accommodation, food, arts and other services	−0,23	−9,96	−30,00		–		–
• Retail	−0,04	−0,25	−5,00		–		–
(iii) Public budget policies							
• Public administration collective services	2,06	2,14	c		c		c
• Public education	0,61	0,71	c		c		c
• Public health	27,71	29,87	c		c		c
• Emergency resource for households	67,31	72,69	–		–		–
(2) Additional shocks for Recovery in 2021							
• Household demand: subway; metropolitan road transport; chartered transport; intercity, interstate and international passenger road; and water transport.	−36,14	−38,89	−40,00		−20,00		–
• Demand and supply for passenger air transport.	−36,14	−38,89	−40,00		−20,00		–
(3) Additional shocks for Recovery in 2022							
• Household demand: subway; metropolitan road transport; chartered transport; intercity, interstate and international passenger road; and water transport.	−36,14	−38,89	−40,00		−34,63		−20,00
• Demand and supply for passenger air transport.	−36,14	−38,89	−40,00		−34,63		−20,00

Source: Authors' own elaboration.
Note: * Hidden values ("-") denote that the variables are endogenous in the period and the term "c" represents that the variable is constant.

rate of −20% by June 2021 (from July 2020 to June 2021). The recovery in this scenario also presents an expansive path similar to that of exponential growth (Appendix A, panel d).

Transport services have also been affected in other countries as shown by an increasing number of studies evaluated the relationship between COVID-19 and the transport sector (Bian et al., 2021; Cui et al., 2021; Gaskin et al., 2021; Hensher et al., 2021; Zhang, 2020). Cui et al. (2021) specified different shocks of the pandemic on China's transport sectors, from both demand and supply sides. The authors found that the passenger transport sectors would have larger decreases in output than the freight transport sectors. The output of waterway passenger transportation would fall by 11.44% in 2020, followed by road passenger transportation (8.96%) and aviation passenger transportation (5.26%), and compared with aviation freight transportation (2.81%) and road freight transportation (2.20%). Gaskin et al. (2021) found that the number of deaths and cases of Covid-19 in the United States were positively correlated with the number of airports, the number of train stations, the percentage of adults using public transportation, and the time spent commuting. Moreover, the pandemic would affect travel behaviors and mobility commuting (Bohman et al., 2021; Hensher et al., 2021). Hensher et al. (2021) analyzed the short-term reduction in money and time costs associated with reduced car and public transport activity in Australia and found $ 1.17 billion worth of reduced time costs associated with reduced employment hours. The work from home experience will likely translate into change dynamics of work in the future, which can lead to major improvements in travel networks and overall cost savings. For Bohman et al. (2021), the possibility of telework may affect different groups differently and exacerbate differences in gender, geography, and mobility. Some studies have assessed the impacts of COVID-19 on air transportation (Andreana et al., 2021; Zhu et al., 2021). For example, Zhu et al. (2021) focused on analyzing the post-COVID-19 recovery of the aviation industry on short-term policy implications.

We also assume that the new business cycle, caused by the retraction in household demand, determines the investor's decision to policy closure until the end of 2022. We attribute this assumption because household demand is the main component of GDP and represents a reference for the behavior of the domestic market in Brazil (about 60% of GDP in 2010). This hypothesis denotes that the change in aggregate investment follows changes in total household demand in 2022 in our economic environment. In this economic environment (closure), the exchange rate is the numeraire, and exports respond only to endogenous changes in the relative price structure and exchange rate. We recognize the exogenous change on the international commodity trading environment with the COVID-19 outbreak, but so far there are no applied studies that can isolate the effect of international trade on Brazilian exports. In addition, there are contracts signed with customers in the international market, which hinders any business change in a short period of time. Our model is national and therefore does not capture feedback effects from the flow of international trade, especially with the country's main trading partners. Therefore, the economic projections in the next section may be more perverse than they appear. This point is an inherent limitation of the model used to analyze the projections of the elaborated scenario. Furthermore, applied studies with CGE models have treated the variations in exports as an exclusively endogenous result or without any exogenous facts.

5. Results

Our study analyzes the effects of the COVID-19 outbreak and provides disaggregated impact comparisons among the following time analysis: (1) common scenario during the strong social distancing measures (until June 2021); (2) "recovery in 2021" scenario post-social distancing period; and (3) "recovery in 2022" post-social distancing period. This strategy allows us to evaluate how the recovery time of public agglomeration sectors affects the Brazilian economy. The results are evaluated in terms of the relative percentage change to the baseline scenario and solved recursive-dynamically (i.e. one-period-at-a-time). Fig. 1 illustrates the effects of the three scenarios on Brazilian Gross Domestic Product (GDP) in percentage deviation from the baseline. The

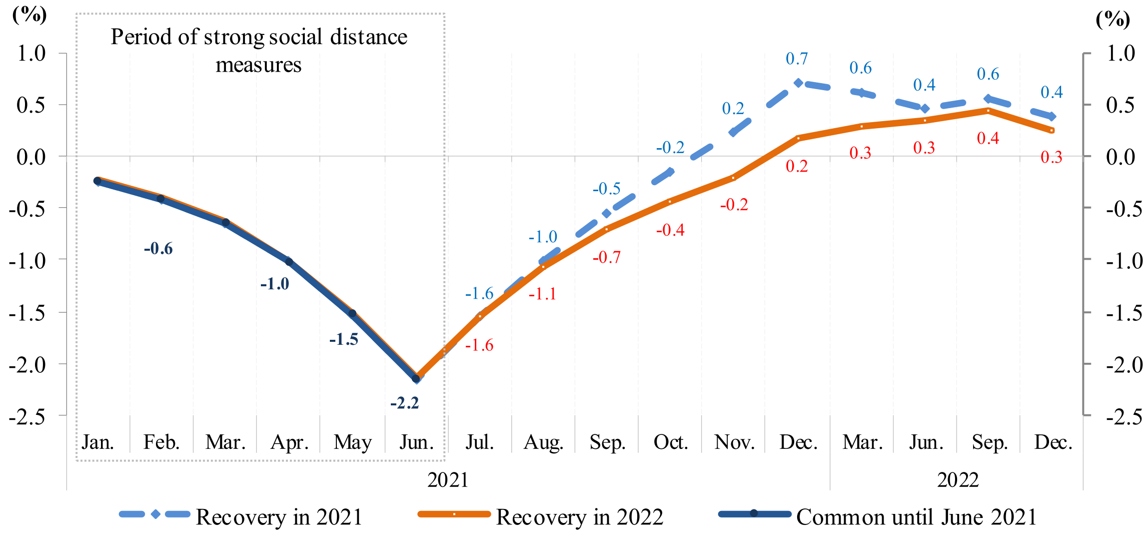

Fig. 2. Economic impacts on the Brazilian GDP time path*.

magnitude of impacts varies across the recovery scenarios. Further, the time path appears to have a curve format between U and L.

Considering the period of social distance measures until June 2021, the Brazilian GDP may accumulate a negative deviation from the baseline of 2.2%, even with the mitigating policies of the public budget. On one hand, if the recovery in demand for the services of public agglomerations increase 50% in relation to the social distancing scenario at the end of 2021 (common + recovery in 2021), the GDP deviation from baseline would be 0.7% in December 2021, accumulating 0.4% in December 2021. On the other hand, as expected, if the recovery takes place in 2022, a greater negative deviation on GDP may occur: 0.2% in December 2021 and 0.3% in December 2022. Therefore, the transition time for the recovery of these sectors matters to the Brazilian economy. The slower recovery tends to deepen the positive effect of GDP, that is, a loss of 0.5% in the growth rate in 2021. A simple calculation gives us the implicit elasticity of GDP related to the recovery time. According to Table 5, the difference in the percentage shock accumulated between the recovery scenarios is −14.62% in 2021, which causes a difference in the effect on GDP growth in the order of −1.5%. Therefore, for every 1% reduction in the accumulated recovery rate in the sectors of public agglomerations, there is an accumulated deviation of approximately −0.03% over GDP growth in six months with an economic environment predicted in the common scenario.

Another conclusive point about the GDP path of Fig. 2 is about the 2022 result between recovery scenarios. Both scenarios point to a 50% recovery in demand from the sectors of public agglomerations, but at different times. The speed or anticipation in the recovery of these types of transport services in the post-isolation period impacts on the recovery of the Brazilian economy in the long term such as in 2022. The difference in result on GDP growth between the two temporal analyses reaches −0.1%, so that the drop in GDP in 2022 is smaller in the "recovery in 2021" scenario (0.4%). This difference between the scenarios could be explained by sequential solutions over a longer time interval, which carries the history of endogenous changes in the Brazilian productive system in each period. These endogenous changes are transmitted through direct and indirect channels in the links of production, consumption, and income of an equilibrium SAM structure, as recognized in our model. Thus, as the adjustment time in "recovery in 2021" scenario 1 is shorter, there is more time for the variables to respond endogenously, which leads to a greater effect, especially if compared to the projections of the "recovery in 2022" scenario.

To observe the contribution of the simulated axes, Fig. 3 shows the relative contribution of each one of them. Panel (a) summarizes these disaggregated results while Panel b presents the time path of the internal and external markets by the decomposition of the expenditure-side real GDP.[3] Finally, Panel c shows the sum of the percentage changes in each period representing the percentage deviation of GDP growth, except for terms of trade. Accumulated variations in terms of trade do not represent contributions to the Brazilian GDP (Panel c). In the period of social distance measures, until June 2021, the effects of preferences observed by the decline in demand for transport services that generate public agglomeration, such as subway, metropolitan road transport, chartered transport, intercity, interstate, and international passenger road, and passenger air transport, is responsible for −0.81% in the negative effect on GDP growth (−2.2%). However, over a longer period (2022), the negative impacts of the labor market on the Brazilian economy are gradually stronger, whose result reproduces the shocks associated with the idea of hysteresis in this type of market.

Simulated recoveries for the sectors of public agglomerations and the shift in preference to consumer goods, durables, and certain services provided to households mitigated the negative effects of the labor market, and, consequently, contributed to the upward trajectory of the Brazilian GDP. For example, when compared to the period of social distance measures, the positive variation in the recovery of public agglomeration sectors over GDP in 2021 accumulates by 0.73 percentage points in June 2022 (recovery in 2021 scenario). This result is the difference between −0.81% of social isolation and −0.08% at the end of 2022 for the sectors with public agglomeration. However, in a scenario of delayed recovery in the group of these transport services, the effect is very painful to the Brazilian economy at the end of 2021, an additional effect of −0.54%. In the recovery in 2022 scenario, the delay could lead to an additional drop of −0.4 at the end of 2022.

Our projections indicate that the Brazilian internal market will recover by the end of 2021 so that the trajectory is similar to a U curve if, and only if, the recovery of public agglomeration sectors is faster, as predicted in the Recovery in 2021 scenario (Fig. 3, panel b). Nevertheless, for any scenario, the Brazilian external market (net exports) decreases until the end of December 2021 because there is a negative function of fluctuations in domestic prices in our model. The positive variations in terms of trade confirm this upward pressure on the

[3] The internal market considers the components of final demand, such as household consumption, government expenditure, investments and eventual variations in inventories. The external market denotes net exports.

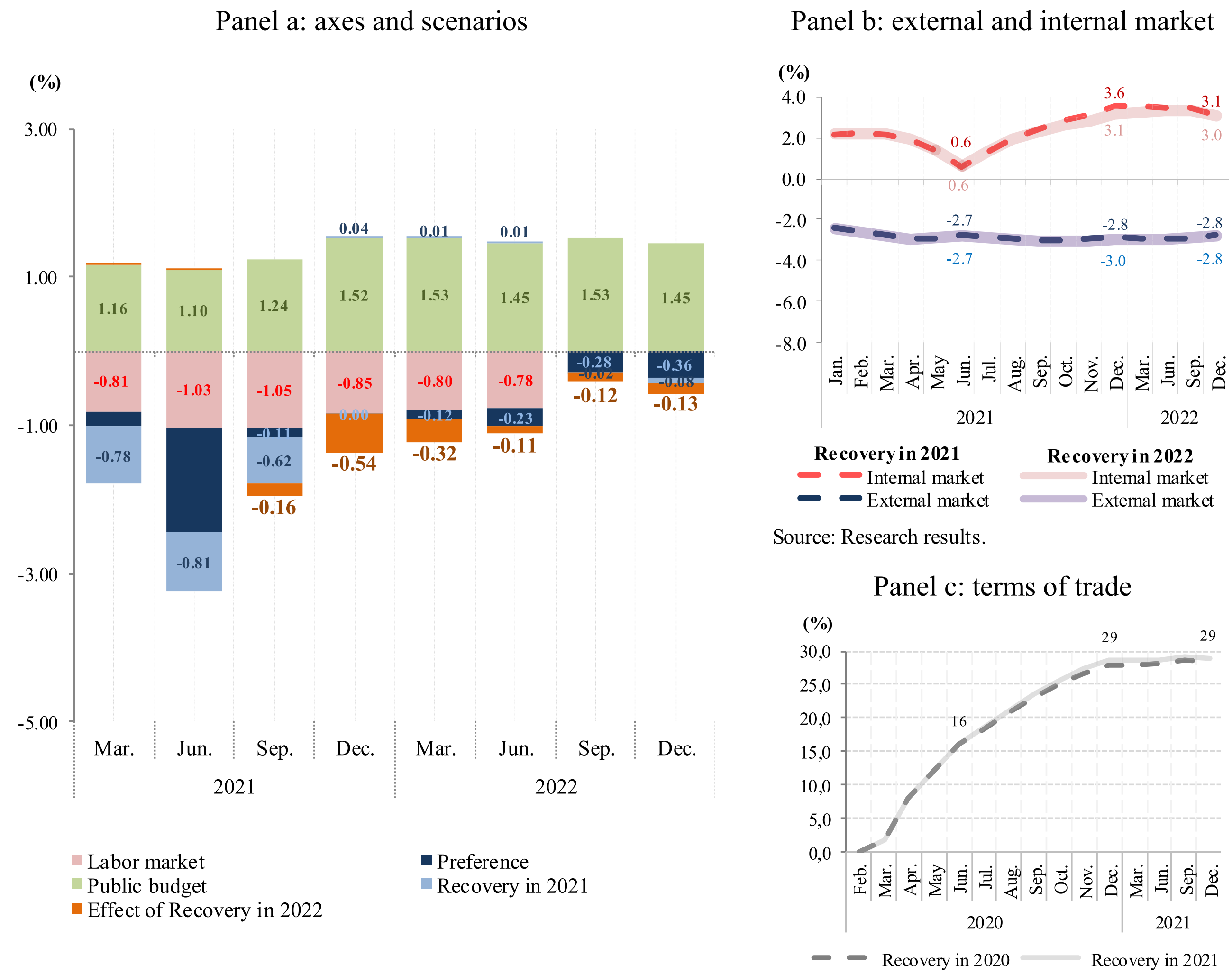

Fig. 3. Terms of trade and contribution for effect on the Brazilian GDP (% cumulative deviations).

domestic prices and production costs, which according to a cost-competitiveness approach, make Brazilian exporters less competitive. The positive price result in the economy occurs mainly because the negative shock in the labor supply causes an upward pressure on nominal wages. The drop in labor productivity in our scenario denotes an increase in the labor amount per unit of output and causes an expansive effect on wages by the demand side of the labor market. The public budget policies induce the expansion of demand in the markets and input requirement per unit of output, also affecting upward pressure on prices in the Brazilian productive system. In summary, the trajectory of the net impact on prices is upward until the end of 2022, even with the shock of change in household preference for certain goods and services (e.g. durable goods, superfluous goods, retail, services).

These macroeconomic effects help to understand the new environment of the Brazilian economy in which transport services are inserted, taking into account the two scenarios for the sectors of public agglomeration. In this step, we can detail the fluctuations in the income of the Brazilian households and observe how these changes influence on the use of public and private transport. Thus, Table 6 provides the impacts on utility and real income available for each typical household. In general, the results suggest that the set of simulated shocks from the scenarios established during and after the period of social distance measures generates a positive impact on this utility and real income available. This result could be explained by the marginal effect of the emergency resource (ER) policy and by the Linear System of Expenses (LES) specification so that the utility is a positive function of the income, given the prices.[4]

According to Table 6, approximately 22.6 million Brazilian households with an income of up to 3 minimum wages mainly have positive effects on utility and real disposable income. This set of families cover up to 70 million people in Brazil, whose number is remarkably close to the target of beneficiaries of the policy of emergency resources to mitigate the adverse effects of the COVID-19 outbreak. Without this policy, the income of beneficiary households reduces by up to 3.2% for Recovery in 2021 scenario, calculated by the difference between the total effect (19.1%) and the marginal effect (22.3%) in Table 6. Consequently, the utility of households grows, that is, the emergency resource policy generates an increase in welfare.

Even if they are not directly benefited by the emergency resource policy, families at the other upper strata of minimum wages are also positively affected. Likewise, the effects on the utility of these other typical families would be less in the absence of the ER policy. This positive deviation from the baseline in the country is due to the indirect channels

[4] Traditionally, there are two forms to analyze welfare in CGE models: the equivalent variation or household utility changes. The equivalent variation is computed from changes in nominal variables in monetary terms, which depends on the trajectory of prices and quantities. This is a problem in a CGE recursive dynamic model as ours. Operationally, we would have to build a comparative static exercise in a dynamic model. To avoid errors in computing the welfare effect, we chose to use the utility variable as a proxy to welfare effects on households.

established in the flow of income and payments in a SAM structure of the model. Families with more than 20 minimum wages would have positive effects on their real income, since they are the main recipients of the capital rentals in the Brazilian productive system. In view of our simulated scenario, the capital price (income) followed the marginal inflationary effect. In the recovery in 2022 scenario, with a slower recovery in the activities associated with public agglomerations, projections indicate that Brazilian households would be marginally worse off. The speed of recovery of public agglomeration transport services also influences the positive and redistributive effects on the income of Brazilian families, especially if associated with emergency resource policies.

These changes in family incomes can impact the demand for transport in a different and disproportionate way, as it depends on the endogenous effects controlled by the LES specification. In this specification, only the demand quantities for goods that exceed subsistence levels change by the same proportion as income. Budget shares of subsistence goods increase when income falls, and decrease when income rises (Betarelli Junior et al., 2020b; Burfisher, 2017). In this special case, in the household consumption basket, it is possible to identify some inferior goods, if they are still subsistence. Table 7 shows the impacts on household demand for public and private transport, especially with two-time frames: a period of social isolation and another for the end of 2022.

With incentives to adopt measures of social isolation in the country and to adjust the budget, households reduce the demand for private[5] and public transport, a composite that brings together the subway and metropolitan passenger road service, as elaborated in Kalinowska and Steininger (2009) and Bruvoll and Larsen (2004). Poorer families with incomes up to 6 minimum wages (mw) are those that would further reduce the demand for both types of transport. The economic effects are pervasive for enterprises offering public transport services, because poorer families are typically the most demanding for this type of transport. The demand for private transport in the isolation period reduces relatively less due to the adjustment of the consumption basket by households according to the variation in income. In addition, in the country there was no strict and comprehensive control over the circulation of private vehicles and, therefore, in our simulated scenario there was no demand restriction for this type of composite. However, the Brazilian government's emergency resource (ER) policy must contribute positively to the increase in demand for public transport. For example, with the ER policy, the demand would decrease 16.0% instead of 43.5% in the consumption basket of the poorest families, with incomes of up to 3 mw, by the end of social isolation.

Regardless of the scenario of recovery of public transport services, as predicted in the simulated scenario, in all income classes (mw) family demand for public transport shows a positive accumulated variation in the end of 2022, with emphasis on 70 million households with incomes of up to 3 minimum wages (16.7% in recovery in 2021 scenario). Again, the marginal effects are most intense when 50% of the activities associated with public agglomerations occur until the end of 2021 in an economic environment like the recovery in 2021 scenario. In general, Brazilian families have reduced the demand for private transport in favor of public transport. In the period, there was an increase in the real disposable income of the poorest families and yet the demand for private transport decreased, whose result indicates a change in preference for public transport. According to our modeling, in these projections, there are no direct effects of intermodal substitution via price between private and public transport.

Likewise, the two simulated scenarios for transport services that generate public agglomerations have implications for the time path of sectoral activity in the country (Table 8). When the recovery of these activities is faster (recovery in 2021 scenario), the production of a large part of the sectors of the Brazilian productive system responds positively, even in the face of the sharp drop in the period of social isolation (June 2021). Only the production of agricultural goods (0.6%) and food (5.4%) grows during social isolation. The food sector is labor intensive, while agriculture is capital intensive. The trajectory of the product of these sectoral activities remains upward until the end of 2021. This happens because in this period the requirement for capital and labor in the production process is relatively less in relation to the year 2022, when other sectors begin to react positively and more intensely in the post-crisis period. This increase in the requirement for primary factors by other industries, especially after 2021, puts pressure on the price of these factors and, consequently, increases the difficulty of production.

The fall in the production of cars, vans and utilities is strong and persistent until the end of 2022, even with the scenarios of recovery of public agglomeration services. This drop is associated with the change in preferences of Brazilian families for durable goods, according to our Covid-19 scenario designed, but also due to the drop in family demand for private transport, as previously mentioned. The sharp drop in production in this industry is even greater than the average reduction in the activity of durable goods in the country. This declining trajectory also persists for the manufacture of tractors, buses, trucks and airplanes, reasonably following the trend of the capital goods industry. The strong reduction in the production of aircraft is mainly due to the behavior of air passenger and cargo transport services in Brazil. As recovery in 2021 scenario envisages a 50% recovery of these types of services in the economy, aircraft production is marginally positive compared to scenario 2. In turn, the production of buses and trucks is recovering more strongly because public transport services already show positive variations at the end of 2021 and 2022 (recovery in 2021 scenario). Bearing in mind that the recovery of these public transport services occurs until the end of June 2022, the recovery of the sectors that produce trucks and buses is slower and still presents high negative variations at the end of 2021 (3.4%).

Services such as subway, metropolitan passenger road and intercity, interstate and international road transport would show a positive cumulative deviation in the end of 2022 if the 50% recovery in production of these activities occurs by the end of 2021 (recovery in 2021 scenario). The trajectories of the production of these services are illustrated in Fig. 4. Especially for these sectoral activities, the time transition after social isolation makes a difference in the annual result. On the other hand, a delay in their recovery, as foreseen in scenario 2, could be painful for the offer of the service at the end of 2021 and 2022, that is, these public agglomeration services would retract above 18.9% in relation to the baseline, accumulating a negative change of approximately less than −9.8% at the end of 2022. Endogenously, there is a change in the supply of these services that distances itself from the simulated shocks for the recovery in 2021 and recovery in 2022 scenarios. These endogenous effects are less observed for air passenger transport. Despite shocks in the recovery of this sectoral activity, the effects on its production are close to the values of the shocks. More specifically, the recovery shock does not reverse the trend of a profound decline projected for passenger air transport. This result can be a reference for possible policy proposals to help this type of transport service in the economy.

6. Conclusion and policy implications

The effects of the COVID-19 outbreak and measures to contain the transmission of the virus have become the main concern in Brazil, especially regarding the negative impacts on the economy, including those related to the supply of and demand for cargo and passenger transport services. The perspectives of enterprises in this field of activity are pessimistic because it not only affects sales and production, but also the continuity and survival of these service providers. These activities

[5] As in Schäfer and Jacoby (2005) and Abrell (2010), the private transport services requires elements of fixed and variable costs and therefore it is a composite formed by gasoalcohol, diesel – biodiesel; other oil refining products; ethanol and other biofuels, automobiles, vans and utilities; aircraft; storage and auxiliary transport services; and financial intermediation, insurance and private pension.

Table 6
Impacts on Brazilian households in 2022.

Households			% cumulative deviations					
			Utility			Real disposable income		
minimum wage (mw)	Number (million)	Members (million)	Recovery in 2021	Recovery in 2022	Marginal effect (ER)	Recovery in 2021	Recovery in 2022	Marginal effect (ER)
up to 3	22,6	70,5	57,6	35,3	42,3	19,1	19,0	22,3
4–6	17,0	57,4	6,7	−3,9	0,4	−1,7	−1,8	0,2
7–10	8,9	30,4	55,7	−1,3	0,8	−0,5	−0,6	0,5
11–20	6,2	21,6	−0,7	1,6	1,4	0,9	0,7	0,8
over 20	3,2	10,7	5,5	4,0	2,3	2,1	1,8	1,2

Source: Research results and POF (IBGE, 2010).
Note: *ER is emergency resource policy. The impact without the ER is the difference between the values of the columns of each scenario and the marginal effect.

Table 7
Household demand for public and private transport.

Household			% cumulative deviations							
			Social isolation (June 2021)				2022			
minimum wage (mw)	Number (millions)	Members (million)	Public transport		Private transport		Public transport		Private transport	
			Without ER	With ER	Without ER	With ER	Recovery in 2021	Recovery in 2022	Recovery in 2021	Recovery in 2022
up to 3	22,6	70,5	−43,5	−16,0	−20,0	0,0	16,7	9,3	−0,3	−0,2
4–6	17,0	57,4	−38,7	−40,1	−17,2	−17,1	−8,6	−15,8	−18,0	−17,9
7–10	8,9	30,4	−35,2	−36,4	−15,2	−15,1	−4,9	−12,1	−15,8	−15,8
11–20	6,2	21,6	−34,3	−35,6	−15,0	−14,9	−3,2	−10,3	−14,7	−14,8
over 20	3,2	10,7	−32,8	−33,7	−14,2	−13,9	−0,6	−7,6	−13,3	−13,4

Source: Research results and POF (IBGE, 2010).
Note: *ER is emergency resource policy.

present interactions between buying and selling with various sectors of the economy, such as the manufacture of buses, oil products, cars and transport parts and equipment. Therefore, the indirect repercussions are not negligible for the Brazilian economy. In view of this critical scenario, political measures have been proposed to mitigate the short-term negative impacts on the various transport services in the country. Service providers that promote public agglomerations are most affected by the Covid-19 outbreak because they depend on both demand of families and companies from other economic activities, such as leisure, business, and commuting trips. Ongoing debates show recurring concern about the time or delay in the effective implementation of these proposed policies that may influence the sector's recovery path in the economy after the period of social isolation.

This study contributed to this debate by projecting the economic effects of the recovery time of public agglomeration transport services on the Brazilian economy, taking into account two main scenarios: (i) a 50% recovery in service demand in 6 months and (ii) a 50% of these services in 12 months. The main purpose was to compare the economic effects between these two scenarios to identify whether the sectorial recovery time has significant implications for the country. The results have highlighted the importance of a fast policy implementation, since the social isolation will be maintained until the end of June 2021 and the economic and business recovery will be gradual and controlled. For this reason, both scenarios were designed with a common scenario that includes fall in the labor supply, reduction in labor productivity, increase in government spending and reduction in household demand for some goods and services (e.g. durable goods, domestic services, goods consumption). These scenarios have been simulated by a dynamic computable general equilibrium model based on a SAM data structure that recognizes the public transport services of agglomerations in detail. The model allowed us to simulate the emergency resource policy of the Brazilian government for the poorest households, as it recognizes the channels established in the income and payment flows between the main economic institutions.

The main findings show that in the period of social isolation the activity retraction in the sectors of public agglomerations is the main contributing factor for a negative effect of the Brazilian GDP growth (2.2%), which evidences the importance of services, such as subway, urban road transport, intercity transport, air transport in the country. In the scenario of faster recovery, the positive effect on GDP growth may reach up to 0.1% at the end of 2022 compared to the slower one. In a scenario of delayed recovery of these transport services, the effect is very painful for the Brazilian economy at the end of 2021, an additional effect of −0.5%. This also confirms the importance of political measures that can recover more quickly these sector activities after a period of strong social distance (e.g. Special Emergency Regime for Urban and Metropolitan; Program for Public Urban Transport for Passengers, labor market flexibility, Guarantee Fund of Operations, grants credit to truck drivers; extension of the deadline for payment of fixed and variable contributions paid by airport enterprise tax credits). The faster recovery of this group of transport services, especially if associated with the Brazilian government's policy of emergency resources, may have a redistributive effect on the family income structure in favor of the poorest households. Household demand for public transport is expected to diminish in the period of isolation, even with the emergency resources policy, but it is also accompanied by a reduction in demand for private transport. As expected by the sectoral interactions of the Brazilian productive system, the manufacture of vehicles, buses and aircraft seems sensitive to the recovery time of the demand for transport services in public agglomerations. The political implications of these results are straightforward. Policies as subsidies, public expenditures, tax incentives and other forms of public capital support for the recovery of subway, metropolitan road, intercity, interstate and international passenger road and passenger air transport services can have positive effects on the economy, households and several sectors of the Brazilian productive system, especially if these measures can promote a faster recovery. The relaxation of social distancing measures does not seem to be an effective alternative, as lives are at stake and there is no guarantee that the demand for this type of transport services will recover with the uncertainty and insecurity of Brazilian households.

Moreover, the passenger transport sector is in crisis in most Brazilian cities due to the drop in demand imposed by restrictive measures to

Table 8
Impacts on the main Brazilian sectors*.

Sectors	June 2021	Dec. 2021		Dec. 2022	
		Recovery in 2021	Recovery in 2022	Recovery in 2021	Recovery in 2022
Agriculture	0,6	2,6	2,7	−2,1	−1,9
Extractive industry	−12,2	−13,8	−14,0	−11,6	−11,7
Food industry	5,4	10,7	10,6	3,6	3,5
Consumer goods industry	−11,2	−13,0	−13,0	−12,2	−12,1
Durable goods industry	−11,2	−10,8	−10,9	−10,3	−10,4
Cars, vans and utilities	−11,9	−10,9	−11,0	−10,8	−10,9
Intermediate goods industry	−8,5	−8,0	−8,1	−7,7	−7,7
Capital goods industry	−10,7	−8,4	−8,6	−8,2	−8,3
Tractors and other machinery	−6,3	−2,0	−2,4	−3,2	−3,2
Trucks and buses and others	−2,6	4,2	3,4	0,3	−0,1
Transport equipment	−9,2	−7,5	−8,0	−7,6	−7,9
Aircraft, vessels and others	−20,2	−10,2	−10,7	−9,3	−9,3
Services	−0,7	2,1	1,7	2,0	1,9
Retail	−1,5	−0,2	−0,3	−1,0	−1,0
Rail freight	−5,3	−4,8	−4,9	−5,3	−5,2
Road freight	−3,9	−1,6	−2,0	−2,8	−3,0
Pipeline	−7,2	−6,4	−6,6	−5,3	−5,5
Subway	−29,8	−6,3	−19,1	1,9	−4,0
Metropolitan passenger road	−33,2	−6,1	−20,2	−2,5	−9,8
Transport school, taxi and chartered	−15,0	−3,3	−10,8	0,8	−1,7
Intercity until international road	−31,3	−5,1	−18,9	1,1	−6,6
Water transport	−11,6	−9,0	−10,4	−8,5	−9,0
Air freight transport	−9,2	−7,8	−7,9	−8,6	−8,5
Air passenger transport	−40,7	−21,4	−35,2	−16,5	−21,0
Cargo handling and storage	−1,2	−6,3	−2,2	−7,6	−6,6
Other activities for land transport	−9,6	−8,2	−8,7	−8,3	−8,5
Ports	−10,1	−8,7	−9,0	−8,7	−8,8
Airports	−11,7	−5,7	−9,7	−3,9	−5,4
Organizations of cargo transport	−1,3	−6,3	−2,2	−7,7	−6,6
Courier and other delivery services	−1,5	−0,6	−0,7	−0,5	−0,5

Source: Research results.
Note: * % cumulative deviations from baseline.

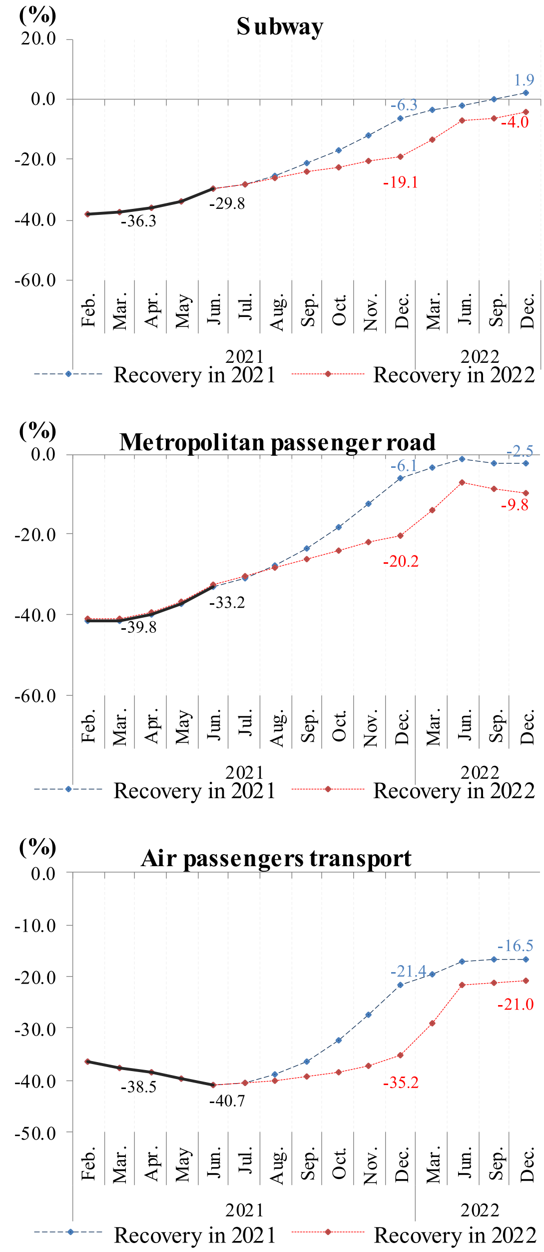

Fig. 4. Effects on some public agglomeration sectors.

combat COVID. Two main short-term measures could be taken by local and federal governments to assist the sector. The first would be to provide subsidized credit to concessionary companies to maintain the payment of employees' payroll. This would mitigate layoffs in the sector. The second would be an emergency renegotiation of government contracts with concessionaires that provide transport services, mainly urban and travel between municipalities. The adversity caused by the pandemic has created new operations for companies and this should be considered in the provision of services while the most restrictive measures last. It is also worth mentioning the need to assign drivers and collectors who work in urban transport as a priority group in the vaccination queue. As long-term measures, the suggestion would be to create a credit line to modernize the fleet, especially for urban buses. In addition, the federal government could launch an investment program on urban roads, mainly bike lanes, as the demand for tele-deliveries increased sharply during the pandemic. However, the federal government of Brazil has not shown interest in creating assistance policies for the sector. An example was the Special Emergency Regime for Urban and Metropolitan Public Transport, which envisaged to reduce the taxes levied on these services to protect the sector (Schiochet, 2020). Such a project would provide an emergency aid of BRL 4 billion to support public transport systems (i.e., buses, trains, and subways) for cities with more than 200 thousand inhabitants (NTU, 2021). This proposal was voted and approved by the Senate of Brazil at the end of 2020 (Bill No. 3364, June 10, 2020). However, the president of the republic vetoed this project. In general, the Brazilian government has implemented some temporary measures to mitigate the risk of survival of economic activities, without any special treatment for the passenger transport sector. The program itself, known as Guarantee Fund of Operations (GFO), was a widespread way of addressing sectoral activities, even with priority for small and medium-sized companies.

In addition, according to the projected results, the contribution of a faster recovery of passenger transport services in public agglomerations would cause the Brazilian GDP growth rate to go from −0.81% in June 2021 to 0, 04% at the end of the same year., the economy would have a large of 0.85 percentage point in 2021. In the scenario of slower recovery, this gain would be 0.27 percentage point. Given these results, the lack of any effective and sufficient financial support for passenger transport services can have serious long-term consequences for the Brazilian economy. Not only because it slows the trajectory of GDP recovery for the subsequent ones, but also because in these types of transport services, unit costs tend to increase due to the reduction of the scale of supply, which can generate painful effects for the poorest families, that are typically dependent on urban passenger transport, both due to the increase in fees charged and the reduction in the provision of services. In this movement, it would end up accentuating even more the income inequality between Brazilian families in the long term.

Declaration of competing interest

None.

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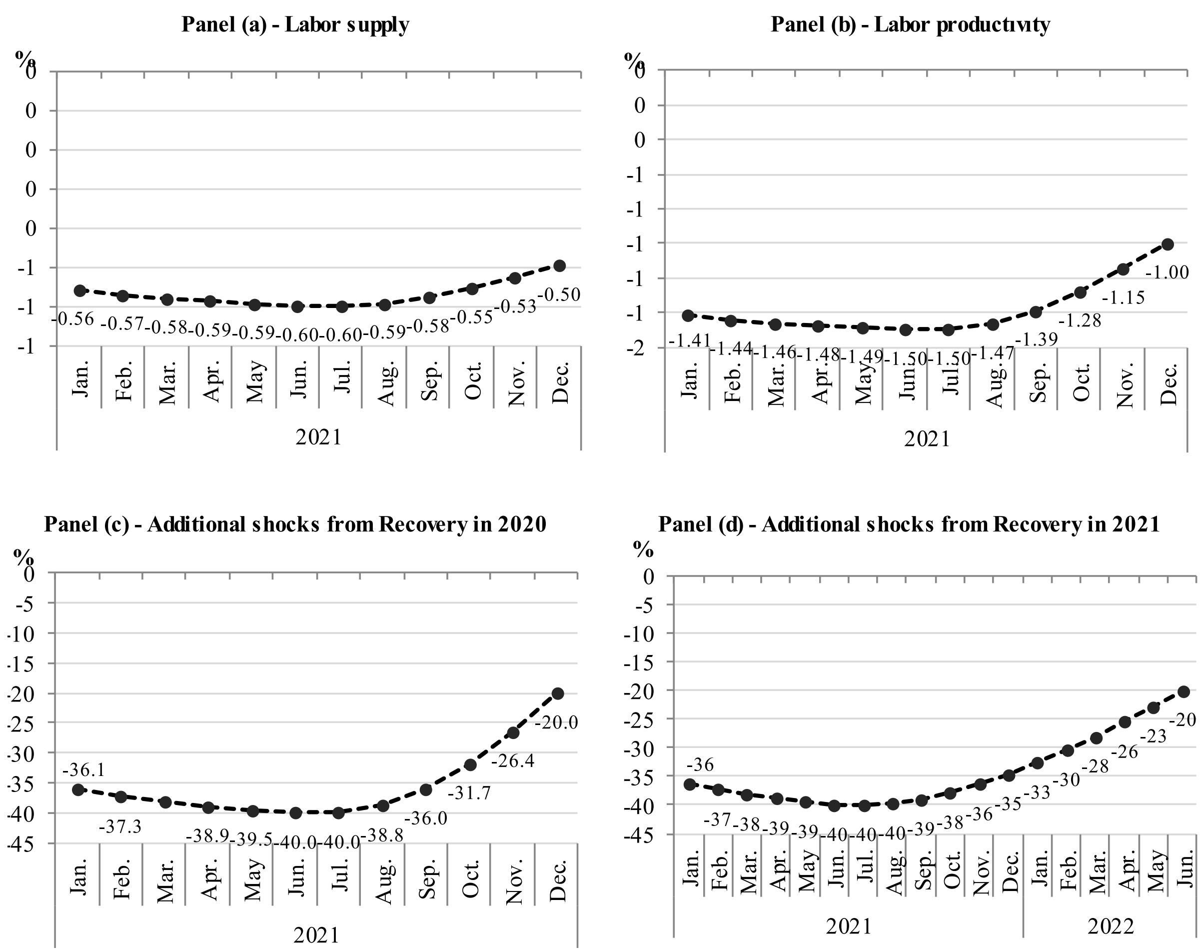
Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2021.06.004.

Appendix A. Selected shocks and trajectories



Source: Authors' own elaboration.

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