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Abstract

Early October 2020, Brazil was one of the countries most affected by COVID-19, both in number of proven cases (3rd) and in number of deaths (2nd), while the first wave of the pandemic is not over yet. This paper intends to provide knowledge on the development of the pandemic in Brazil and therefore to feed into the reflection on the policies implemented or to be promoted to combat it. The study has two objectives: to identify the risk factors for contracting COVID-19 and dying from it, according to different social categories; to highlight potential transmission channels as well as the effect of a number of measures. Carried out at the level of all Brazilian municipalities (5,570), the analysis is based on the matching of different statistical and administrative databases, involving the processing of tens of millions of observations. To our knowledge, it is the first of its kind in Brazil. The econometric analysis conducted in five points in time shows three main results. First, structurally vulnerable populations are the most affected: non-white, poor, poor health, favela residents, informal people, highlighting the effect of

socioeconomic inequalities when facing of the disease. Second, "density" (both within neighborhoods and housing) and "mobility" are decisive. Third, we highlight some policies consequences. In the *municipios* where containment measures were taken earlier, the pandemic is better controlled. The *Auxilio emergencial* has a mitigating effect in localities where there are relatively more informal workers, who can, thanks to it, limit their business trips and better protect themselves. Finally, COVID-19 hits the most in the *municipios* more favorable to President Bolsonaro. The president's ambiguous speech and attitudes may induce his supporters to adopt risky behavior more often and to suffer the consequences.

Keywords: Brazil, COVID-19, Municipalities, Socioeconomic Inequality, Informality, Public Policy

JEL codes: I14, I18, I38, 017, 054

Resumo

No início de outubro de 2020, o Brasil era um dos países mais afetados pela COVID-19, tanto em número de casos comprovados (3º) quanto em número de óbitos (2º), enquanto a primeira onda da pandemia ainda não tinha terminado. Este artigo pretende fornecer novos conhecimentos sobre o desenvolvimento da pandemia no Brasil e, portanto, alimentar a reflexão sobre as políticas implementadas ou a serem promovidas para combatê-la. O estudo tem dois objetivos: identificar os fatores de risco para contrair e morrer de COVID-19, segundo diferentes categorias sociais; realçar os canais de transmissão potenciais, bem como o efeito de uma série de medidas. Realizada ao nível de todos os municípios do país (5.570), a análise baseia-se no confronto de diferentes bases de dados estatísticos e administrativos, envolvendo o processamento de dezenas de milhões de observações. Até onde sabemos, é o primeiro estudo do gênero no Brasil. As estimativas econométricas, referentes a cinco datas differentes, mostram três resultados principais. Em primeiro lugar, as populações estruturalmente vulneráveis são as mais afetadas: não brancos, pobres, saúde precária, moradores de favelas, trabalhadores informais, evidenciando o efeito das desigualdades socioeconômicas frente à doença. Em segundo lugar, os fatores de "densidade" (tanto dentro dos bairros quanto na habitação) e "mobilidade" são decisivos. Terceiro, destacamos a influência de elementos da política e similares. Nos municípios onde as medidas de contenção foram tomadas mais cedo, a pandemia é melhor controlada. O Auxilio Emergencial tem um efeito mitigador nas localidades onde há relativamente mais trabalhadores informais, que podem, graças a ele, limitar seus deslocamentos para o trabalho e proteger-se melhor. Finalmente, a CoVid-19 causa mais estragos nos municípios mais favoráveis ao presidente Bolsonaro. O discurso ambíguo do presidente poderia estar induzindo seus apoiadores a adotarem comportamentos de risco com mais frequência e a sofrerem as consequências.

Palavras-chave: Brasil, COVID-19, Municípios, Desigualdades Socioeconômicas, Informalidade, Políticas Públicas

Résumé

Début octobre 2020, le Brésil était l'un des pays les plus touchés par le COVID-19, aussi bien en nombre de cas avérés (3ème) qu'en nombre de décès (2ème), alors que la première vague de la pandémie n'est pas encore terminée. Cet article se propose d'apporter des éléments de connaissance sur le développement de la pandémie au Brésil et partant d'alimenter la réflexion sur les politiques mises en œuvre ou à promouvoir pour la combattre. L'étude se donne deux objectifs : identifier les facteurs de risque de contracter le COVID-19 et d'en mourir, en fonction des différentes catégories sociales ; mettre en évidence de potentiels canaux de transmission ainsi que l'effet d'un certain nombre de mesures. Réalisée au niveau de l'ensemble des *municipios* du pays (5 570), l'analyse est basée sur l'appariement de différentes bases de données statistiques et administratives, impliquant le traitement de dizaines de millions d'observations. Elle est à notre connaissance la première du genre au Brésil. Les estimations économétriques, réalisées à cinq dates différentes, font ressortir trois principaux résultats. En premier lieu, les populations structurellement vulnérables sont les plus touchées : non blancs, pauvres, santé précaire, habitants des favelas, informels, mettant en lumière l'effet des inégalités socioéconomiques face à la maladie. En deuxième lieu, les facteurs de « densité » (aussi bien au sein des quartiers que des logements) et et de « mobilité » s'avèrent déterminants. En troisième lieu, nous mettons en évidence l'influence d'éléments de politiques et assimilées. Dans les *municipios* où les mesures de confinement ont été prises le plus tôt, la pandémie est mieux contrôlée. L'Auxilio emergencial a un effet atténuateur dans les localités où il y a relativement plus de travailleurs informels, ces derniers pouvant grâce à lui limiter leurs déplacements professionnels et mieux se protéger. Enfin, le CoVid-19 fait plus de ravages dans les *municipios* les plus favorables au président Bolsonaro. Le discours ambigu du président induit ses partisans à adopter plus souvent des comportements à risque et à en subir les conséquences.

Mots-clef : Brésil, COVID-19, Municipalitées, Inégalités socio-économiques, Informalité, Politiques publiques

Introduction

When we closed this text, Brazil was the second country in the world most affected by COVID-19 in number of deaths and third in number of confirmed cases. Our study intends to provide elements of knowledge on the development of the pandemic in Brazil and help to understand the policies implemented or to be promoted to combat it. While epidemiological studies are increasing, studies on the socio-economic factors of COVID-19 transmission remain rare; a gap that is all the more problematic because while the biological characteristics of individuals play a role in themselves, they are not the only ones. Their effects depend closely on their interaction with human, individual and collective behavior. Only the concomitant consideration of these two dimensions can allow a better understanding of the evolution of the pandemic and the effectiveness of the resulting policies. This is what this work intends to contribute to. To our knowledge, this is the first such study in Brazil.

Our study has two main objectives: to identify the risk factors for contracting COVID-19 and dying from it, according to different social categories; to highlight potential transmission channels and the effect of a number of measures. Carried out at the level of all of the country's 5,570 municipalities (*municípios*), the analysis is based on the matching of different statistical and administrative databases, involving the processing of tens of millions of observations.

This municipality approach, which complements analyzes at the individual level, has a number of advantages. We will mention four main ones: it is the only one that guarantees the completeness of all municipalities in the country; the effects of the pandemic are manifested not only at the individual level but also at the collective level; socio-economic surveys do not count deaths, while health surveys are poor in socio-economic descriptors; lastly, and above all, the policies to fight the disease are carried out at the municipality level.

On the other hand, it is not without limits. We will highlight the non-specific problems in Brazil of counting victims (deaths and especially proven cases, due to a faulty testing policy). Regarding the interpretation of the results, two caveats should be emphasized. On the one hand, the analysis by municipalities cannot be mechanically transposed in

terms of individual risks. On the other hand, the econometric models tested make it possible to estimate the association between the victim rate and the various factors used, corrected for structural effects. Therefore, the study does not claim to identify the causal impact of these same factors.

The first part of the paper presents a brief review of the international and Brazilian literature on the subject. The second gives an overview of the Brazilian context, discussing the epidemiological situation and the policies implemented. The third details the approach, the data sources and provides initial descriptive statistics. The fourth discusses the results and the dynamics since the start of the pandemic. Finally, the lessons and perspectives are presented in the conclusion.

1 Socio-economic factors and CoVid19: a brief review of the literature

The growing literature on Covid-19 is very recent and many studies are still preliminaries and have not been peer-reviewed for publication in academic journals (Brodeur et al., 2020). The literature is essentially epidemiological by nature, and to a lesser extent economic. In this brief review of the literature, we will provide an overview of the available socioeconomic analyzes on Brazil. We will also present some papers taken from international literature. As it is impossible to exhaustively cover them, since there are many, we will be contented to mention only two examples (concerning the United States and France), which adopt an approach based on geographic data (by municipalities) as the present paper.

In the Brazilian case, a few studies are already available and they are often restricted either to a region or to the analysis of certain aspects, which is a limitation given the scale of the pandemic and the size and diversity of Brazil. They seek to identify the characteristics of infected people or to measure the different risks of infection with COVID-19.

The largest study about COVID-19 prevalence in Brazil (Hallal et al., 2020) results from a huge testing program conducted by a team led by the Federal University of Pelotas. Along with the serological results, information on socioeconomic characteristics (gender, age, education, ethnicity / skin color, household characteristics) and on compliance with social distancing measures was collected. The study covered over 55,000 randomly selected participants from 133 different cities across the country. The survey was carried out in two periods (May and June 2020). Unfortunately, the disruption of federal funding prevented the continuation of testing as well as the deepening of the knowledge about the disease, which in June was not only on an increasing trajectory but also showed significant geographic shifts.

Apart from the serological information which suggested, among other things, that the under-notification of cases was around 70%[1], the socio-economic information highlighted the fact that the disease affected different categories of the population. Regarding ethnicity, the prevalence rate of natives (*índios*) was found to be much higher than that of other ethnicities, being followed by the rate of blacks and *pardos*, in all cases much higher than that of white (6.3, 3.6, 3.4 and 1.4 respectively). Women appeared to be less affected by the disease when first tested in May. In contrast, the prevalence rate at the second test in June was higher than that of men. In terms of age, the highest rate is reached between 30 and 59 years old. The indicators relating to living conditions highlighted the sanitary fragility of the poorest, with the prevalence increasing with the number of inhabitants per household and decreasing with the household wealth.[2]

In an article published by *The Lancet*, Baqui et al. (2020) seek to identify the individual risk factors associated with mortality due to COVID-19. To do this, they use the national SIVEP-Gripe database[3], which gives for each hospitalized patient a certain number of socio-economic characteristics: age, sex and region, skin color according to the IBGE typology and comorbidities. According to this database, 19,940 patients tested positive. Due to a large number of non-responses, the analysis ultimately concerns a sample of 6,882 patients for whom the authors have all the variables. They compare the profile of those who died (3,254) and those who survived (3,628) till May 4, 2020. Beyond the classic factors (age, comorbidity), their main result concerns the risk of mortality, estimated from a Cox model, by skin color and region. All things being equal, the *Pardos* and *Negros* have a 45% and 32% higher risk of dying than the *Brancos*. States located in the North region were more affected at this time.

With the objective of assessing the inequalities of Brazilian society in the face of Covid-19, Nassif-Pires et al. (2020) calculates the risks of contamination and death on the basis of the three dimensions of vulnerability to disease: the so-called "social" dimension,

[1] "The ratio of estimated infections to reported cases was equal to 10·3" (p. 6).

[2] Concerning wealth, households were classified by quintiles using a composite index of household assets.

[3] "Sistema de informação de vigilância epidemiológica da gripe", from Health Ministry (http://plataforma.saude.gov.br/coronavirus/dados-abertos/).

associated with working and housing conditions[4], that relating to access to health services, and finally, that concerning the medical risks[5]. The authors construct social and medical vulnerability indices for the different categories of the population – grouped by sex, race, income and education level - and complete the analysis with information on inequalities in access to the health system by region and by type of system (private or public). The risks are higher among natives (*índios*), blacks and *pardos*. In general, women are less vulnerable, although black, *parda* and native women show higher values than the whole population average. In terms of income, the risk decreases almost continuously along the deciles and the racial inequalities observed are reproduced for all levels. A lower level of education is associated with a higher risk. Regarding medical characteristics, data indicates that the existence of comorbid conditions is greater for the less educated population, which reinforces the higher risks found for vulnerable populations.

In a similar work, Nunes et al. (2020) also analyzes vulnerabilities relating to health, work and housing characteristics. The authors use the same sources as the previous study but use additional variables and a different methodology (probability estimates from a Probit model). For health-related vulnerability, aside from information on comorbid factors, the authors add information on smoking and obesity. Economic vulnerability is captured by work informality. Finally, for the vulnerability of housing, apart from access to the water and sewer network and the home density (promiscuity), the authors add variables concerning the type of construction and the existence of garbage collection. Analysis of the results by level of education, age and state of the federation shows that while the elderly are more vulnerable in terms of health, young people are not spared as almost half of the population under 60 years of age present at least one health risk factor and are the most vulnerable concerning the work informality. In fact, these characteristics often overlap. The analysis by state of the federation shows significant regional disparities, both

[4] The risk factors concerning working conditions are whether the job has been declared essential by the government, the informality, having an own vehicle and access to the internet. Factors associated with housing depend on the number of inhabitants and access to drinking water and sewer network. The data used come from the PNAD Survey.

[5] The considered medical risks, pointed out by the medical literature, are: age over 60 years, diagnosis of diabetes, hypertension, asthma, pulmonary, coronary or chronic kidney disease. The authors use individual data from the "Pesquisa Nacional de Saúde" (National Health Survey, IBGE, 2013).

in terms of health and work characteristics of individuals, but also in terms of housing vulnerability. In general, health vulnerability is higher in the richer states (South and South-East regions) while economic vulnerability is higher in the poorest states (North and, to a lesser extent, North-East). The housing vulnerability follows the same geographic distribution, despite the existence of a considerable proportion of homes in the South and South-East without access to water, sewer and garbage collection networks. This greater housing vulnerability in the poorest regions of the country reinforces the economic vulnerability and the fragility of the health systems in these same regions.

In a technical note, a group of researchers from the PUC-RJ analyzes the socio-economic dimensions of COVID-19 fatal cases at the national level (Batista et al., 2020). From a sample of 43,906 patients confirmed to CoVid19, drawn from the relative data "Síndrome Respiratória Aguda Grave" (SRAG) database from the Ministry of Health until May 18, 2020, they identify a sub-sample of 29,933 patients who have either recovered or dead. Based on simple cross tables, the study shows that the case-fatality rate increases with age. It is also higher among natives, *negros* and *pardos*, as well as among people with low education levels. Finally, the case-fatality rate is higher in the poorest municipalities (according to the 2010 IDHM ranking). The skin color effect is verified at any age, level of education and type of internment. Only in the high IDHM *municipios*, difference between whites and not whites (*pardos* and *negros*) case-fatality rates is not significant.

Alongside studies with national coverage, others focus on more restricted sets. Miranda and her co-authors (2020), for example, are interested in the socio-economic aspects of the spread of Covid19 within neighborhoods of the city of Rio. Neighborhoods are classified by quintile of the Social Development Index (SDI),[6] calculated using data from the 2010 Census, and is interested in the distribution of infection, mortality and case fatality rates based on data available on June 13, 2020 (i.e. approximately 43,000 cases and 7,000 deaths). Descriptive statistics show that the infection rate gradually spread from wealthy neighborhoods to others. They show that the case fatality rate is higher in poor

[6] This index is a modified version of the UN HDI Index – for more information, see http://portalgeo.rio.rj.gov.br/bdario/

neighborhoods (regardless of age), but that the death rate varies little according to IDS quintiles. It would even tend to be superior in wealthier neighborhoods.

The Polis Institute (2020) analyzed the mortality rate from COVID-19 by neighborhood in the municipality of São Paulo according to skin color. The direct comparison of the indicators shows higher absolute values for white people, but this comparison does not take into account differences in the age profiles of white and non-white groups. The *negros* and *pardos* forms a younger population and therefore mortality should be lower than observed. To correct this bias, an usual epidemiological procedure has been adopted. The death rates for both whites and non-whites were recalculated assigning weights to different age groups. Thus, a standardized death rate was obtained by applying the age-composition weighed death rate for white and non-white groups. In the case of São Paulo, the standard mortality rate for *negros* and *pardos* is lower than that observed, while for whites, the standardized rate is higher than observed. This suggests that there is an excess mortality of blacks, corresponding to 30% of the number of expected deaths. In the case of whites, the observed number is 13% lower than the number of expected deaths.

Another work analyzes the prevalence of COVID-19 in Rio Grande do Sul, based on a serological survey (Silveira et al., 2020).[7] The state of Rio Grande do Sul is one of the wealthiest states in the federation. It also has a predominantly white population and the highest percentage of seniors in the country. As for the country as a whole, the prevalence in Rio Grande do Sul is higher for women and for non-whites, it increases with age and decreases with level of education.

The study by Argentieri Mairani et al. (2020) differs from the others previously cited, both by the addressed topic and the applied methodology. The authors analyze the effect of President Bolsonaro's skeptic attitude towards the Covid-19 pandemic. The authors conduct a difference-in-difference analysis of both the *municipios* favorable to the president (those where the president had more than 50% of total votes in the first round of the 2018 election) and the others, before and after the demonstrations of March 15, 2020. Among the 1,050 *municipios* that registered at least one case of COVID-19 before

[7] This study was carried out by the team responsible for the national study cited above (Hallal et al., 2020).

April 15, 250 experienced pro-government protests. Several indicators of the impact of COVID-19 are being tested (including excess hospitalizations and excess mortality). This natural experiment shows that *municipios* experiencing protests registered more hospitalizations and deaths than the others. This effect is due both to agglomeration during gatherings but also to more lax attitudes in respect of social distancing, following presidential speeches and position.

A second political economy study seeking to assess the importance of the president's speeches is that of Ajzenman et al. (2020), which estimates a fixed-effects panel model for Brazilian municipalities. The results show that, in pro-Bolsonaro municipalities (identified by the 2018 electoral results), the mobility of citizens increases consistently in the week following acts or speeches of the president minimizing the effects of the pandemic and discouraging the compliance of social distancing. This effect is stronger in municipalities with a significant local media, a high number of twitter accounts (social network widely used by the president) and with a high proportion of evangelists.

At the international level, McLaren (2020) analyzes racial disparities in COVID-19 mortality at the level of American counties. This study is the one that comes closer to ours in terms of method and research questions. From a sample of 3,140 counties, representing 322 million US residents, and by crossing mortality data (as of May 19, 2020) and census data, the author shows that the proportion of deaths is highly correlated with the proportion of blacks (and natives) in the country, and that this correlation is robust to the introduction of control variables such as education, income, types of jobs (occupations, work-related trips, and teleworking possibilities) as well as the benefit of health insurance.

The study by Brandily et al. (2020) is probably the most ambitious of the analyses at the aggregate level of municipalities for the case of France. It shows that the epidemic disproportionately affects the poorest municipalities. Among the potential transmission mechanisms, the degraded housing conditions (in particular, the level of promiscuity) as well as the degree of exposure linked to the job appear to be the more solid explanations. This work has many advantages over other studies. First, the variable of interest is not the number of deaths recorded, whose biases are unanimously recognized (different underestimation according to the population categories), but the excess of mortality over

the number of deaths in the last year. Then, it is based on a pairing of several particularly rich, almost exhaustive databases of 30,000 French municipalities. Finally, it uses a quasi-experimental (triple difference) approach to estimate the causal impact of the pandemic.

To conclude this brief review of the literature, almost all existing studies in Brazil indicate that vulnerability - estimated or observed (by the rate of infection or death) - is higher for more fragile populations from several points of view. Studies are unanimous in pointing out that non-whites are more affected by COVID-19, as are older people. Evidences on the higher vulnerability to COVID-19 of the most fragile groups are also underlined on three other dimensions: economic conditions (income and work), housing - the two being linked - and the level of education. The only non-consensual aspect is the differences between men and women. Although it can be expected that women stay at home more than men - for economic and cultural reasons[8] - with a reducing effect on the contamination rate, the results differ between studies.

The present study claims to go beyond the above mentioned analysis by integrating a wide set of variables in order to cover the multiple dimensions of the factors affecting the evolution of the pandemic - such as socioeconomic, demographic, cultural (political and religious) and those associated with economic policies. In this sense, our research seeks to make an exhaustive analysis of the explanatory factors of the evolution of Covid-19 in Brazil, using a methodology that allows an assessment of the isolated impacts of each explicative factor. As the analysis is conducted at the municipality level and at different dates to monitor each factors impact over time, it provides insights which complement existing studies.

[8] Nassif-Pires et al. (2020b) reproduce data from a survey in the US that shows that women feel more concerned by the disease, report having changed their routine more often and have lost their jobs or reduced working hours more than men. This does not seem to be very different in Brazil where several articles show that the number of hours dedicated to household work is higher for women and that during the pandemic unemployment have been affecting more women than men because of their higher presence in the service sectors - domestic workers, in particular - and in the informal sector.

2 The Brazilian context

2.1 The epidemiological situation

Brazil is one of the countries most affected by the COVID-19 pandemic. As of October 2020, according to official sources, it was the second country in the world, behind the United States, with over 150,000 deaths, and third, behind the United States and India, with over 5,000,000 confirmed cases. These figures should be taken with caution, due to massive underestimation (especially for the number of cases) and poor data quality in most countries of the world. However, Brazil's particularly low test rate can only confirm Brazil's relative position (see Part III for a discussion). Compared to the country's population, Brazil is not the most affected. However, with 710 deaths and 24,000 confirmed cases per million inhabitants, the country remains at the forefront of the pandemic (see **Table 1**).

Table 1: The COVID19 10 most affected countries in the world (14, October 2020)

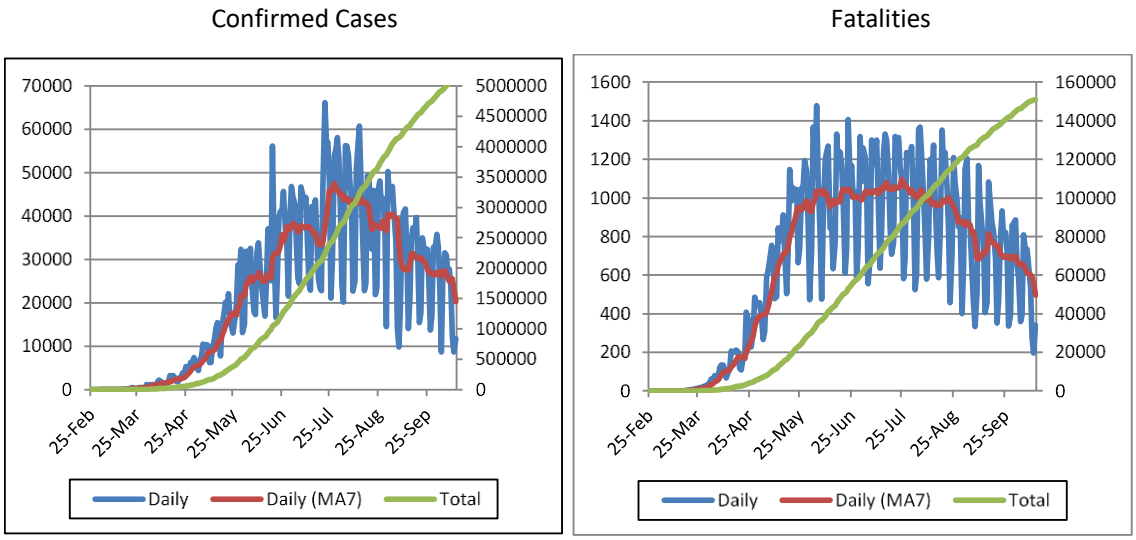
	Fatalities	**Mortality rate** (by million/inhab)	**Confirmed Cases**	**Infection Rate** (by million/inhab)
United-States	221,431	668	8,126,349	24,510
Brazil	**151,161**	**710**	**5,117,825**	**24,028**
India	111,272	80	7,301,804	5,276
Mexico	84,420	653	825,340	6,382
UK	43,155	635	654,644	9,629
Italy	36,289	600	372,799	6,168
Peru	33,419	1,010	853,974	25,799
Spain	33,413	715	937,311	20,045
France	33,037	506	779,063	11,928
Iran	29,349	348	513,,219	6,088
World	**1,094,386**	**140**	**38,640,757**	**4,957**

Source: "COVID-19 Coronavirus Pandemic," Worldometer, last updated October 14, 2020, https://www.**worldometers**.info/coronavirus

Figure 1 shows the trend in the number, daily and cumulative, of confirmed cases and deaths. In both cases, the number of victims is still high although declining, which shows that the pandemic is not under control. After a rapid acceleration in the first three months (between March and May), the number of deaths has reached a plateau. From late May to mid-August, the death toll stabilized at a high level of around 1,000 per day. Since then, there has been a gradual decline. However, early October, there were still around 600 deaths per day on average. As for confirmed cases, a first plateau of around 25,000 cases per day was reached in early June. This number increases to around 37,000 in the first

half of July, then reaches a new peak (46,000 on average at the end of July), only to decline from that date. In early October, the moving average was around 25,000 cases per day.

Figure 1: Confirmed cases and fatalities due to COVID-19 (13, October 2020)



Source: Ministry of Health/Fiocruz (https://bigdata-covid19.icict.fiocruz.br/, accessed 13, October 2020); authors' calculations.

Note: MA7 : Moving Average (7 previous days). **Total** on the right scale.

Figure 2 shows geographically the evolution of the mortality rate and the infection rate per *municipios* over time. We can observed that the Northeastern and the Southeastern littoral regions were the first affected. Its movement toward the interior of the country is also clear.

2.2 Policies responses

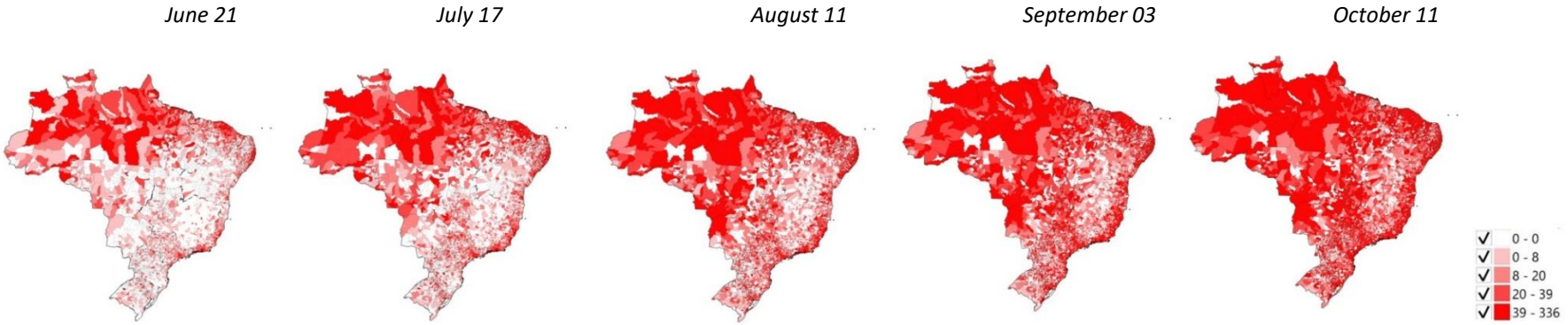
In terms of policies responses to the coronavirus pandemic, two types of measures have been taken worldwide: public health measures – called non-pharmaceutical interventions (NPI) – to reduce contact rates in the population and thereby the transmission of the virus ; and economic policies aiming at reducing the negative effects of the pandemic crisis on households and firms.

Since the annoucement of the Covid-19 pandemic by the World Health Organization, on March 11, 2020, "social distance" is the main NPI recommended to control the spread of

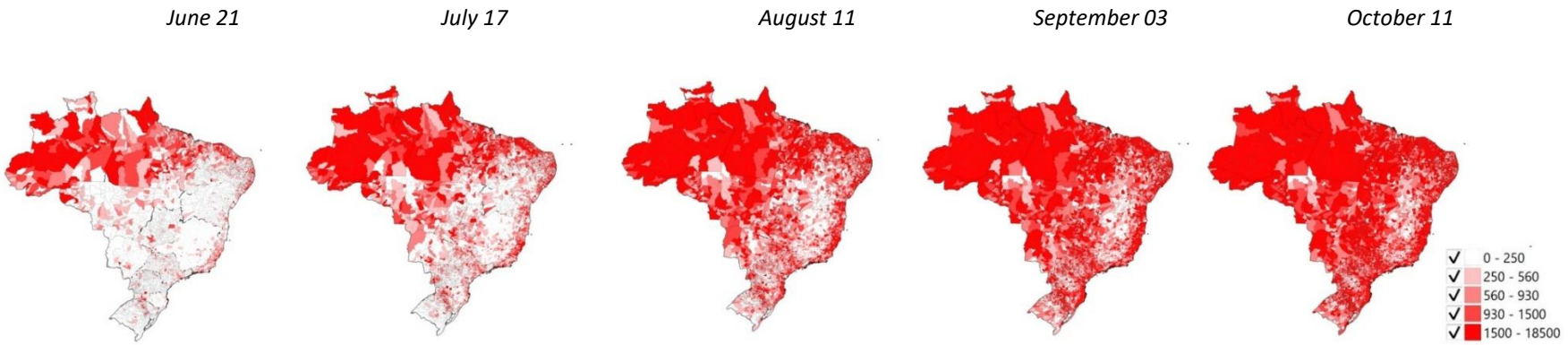
the new coronavirus. National governments worldwide have defined a series of actions to implement this measure, such as the suspension of non essential economic activities, isolation at home, remote work and mobility restrictions on the cities.

In Brazil, the main response of President Bolsonaro has been to deny the virus danger, announcing it as a "small flu" (*gripezinha*), and discouraging measures of social distancing and lockdown, insisting on the negative economic consequences for the country. In line to follow President Trump conduction to the pandemic crisis, there were very particular elements in Brazilian action, taking account the combination of absence of a comprehensive NPI and internal political crisis at the national level of the government. In the midst of a pandemic, there were two changes of the Minister of Health, and since then public health crisis has been conducted by a military minister. Such disarray at the central public administration sows confusion and has negative effects on the relaxation of mitigation measures by the population.

Figure 2: Evolution of the mortality rate per *municipios* (per 100 000 inhabitants)



Evolution of the infection rate per *municipios* (per 100 000 inhabitants)



Source: Ministry of Health/Brasil.IO (https://data.brasil.io/dataset/covid19/_meta/list.html, accessed 11 August 2020); authors'calculations.

In the lack of national coordination of social distancing policies between the different spheres of government in Brazil, policies were adopted in a decentralized manner by sub-national governments (by states and, to a lesser extent, by municipalities). Fonseca et al. (2020) argue that in view of the negationist position of the President of the Republic and the lack of unified and coordinated action at the national level by the Ministry of Health, subnational governments (state governors and city mayors) took the lead in facing the pandemic crisis. This was a real change in the conduction of health policy when compared to the successful responses in the epidemics of HIV / AIDS, Hepatitis C, and H1N1 Influenza.

According to Moraes, Silva and Toscano (2020), in March 2020, all Brazilian states had introduced measures regarding the suspension of schools and social events, as well as the suspension of non-essential economic activities. In April, states started to elaborate plans to make social distancing measures more flexible and were adopted in 21 states by the end of July 2020. These authors emphasize the great heterogeneity in the characteristics of these plans in terms of format, technical criteria and transparency, as well as in the number of municipalities following the state plan. Moreover, the absence of an adequate testing policy, in which cases are identified and contacts are tracked, hinders the execution and success of these plans.

Far from questioning the correctness of the recommendation to “stay at home”, these measures unleash an economic crisis unprecedented in recent history and reveal huge socioeconomic inequalities to face the uncertainties of the pandemic. Basically, this measure falls more heavily on those who have greater difficulties in keeping their work at home and guaranteeing income to support their expenses. Emergency social policies to guarantee basic income for the most vulnerable and policies to support workers and companies are essential so that the pandemic crisis does not deepen socioeconomic inequalities and poverty.

Concerning the economic policy response, the Brazilian government has implemented several measures to tackle the negative effects of the pandemic. Silva (2020) presents the federal government's emergency economic policy in two sets of measures: of a fiscal nature, aimed at guaranteeing the families' income, supporting companies and providing

financial assistance to states and municipalities; and the other related to liquidity provision and regulatory capital policies, oriented to the stability of the financial system and the expansion of the credit supply. We will analyze the fiscal measures below.

The Brazilian government has launched an emergency plan to guarantee a minimum income for the most vulnerable people. The Emergency Aid for People in Vulnerable Situations (AE, Auxílio Emergencial a Pessoas em Situação de Vulnerabilidade), the most popular measure during the pandemic, was created by Law no. 13,982 / 2020 in April 2020. After a strong civil society campaign, the federal g overnment's proposal was changed by Congress, implementing an Emergency Basic Income of R$ 600 per month, instead of R$ 200 proposed by the government.[9] The monetary aid was limited to two beneficiaries per family, being paid double in single-parent families headed by women and considering reaching a maximum amount of R$ 1,800 in the case of a single-parent family headed by a woman who would have another adult also entitled to the benefit. At the end of the 3 months experience, the government opted for its extension until August 2020. In September the benefit was extended until December 2020, however for a monthly value reduced by half.

This assistance is basically intended for informal workers in vulnerable situations, and is also accompanied by the expansion of the Bolsa Família Program to an additional 1.2 million families. The following eligibility rules were defined: being over 18 years of age, having a total monthly family income per capita of half a minimum wage (about R$ 522.5) or total family income of less than 3 minimum wages (R$ 3,135), not receiving any other social benefit, except Bolsa Família, not being a formal employee, having taxable income below R$ 28,560 in 2018.

The federal government expanded the Bolsa Família (BF) cash transfer program, using the Cadastro Único (Cadúnico) records to identify potential beneficiaries and, equally, to increase the benefit amount for families within the BF Program. For families that already received BF, the amount of the family allowance, if lower, is automatically replaced by

[9] US$ 1 = R$ 5.5.

the amount of emergency aid. For families registered in *Cadúnico*, assistance was granted automatically for eligible families.[10]

Such emergency action, however, reveals enormous logistical challenges (operational and communication) for receiving the benefit and weaknesses of the social protection system. Most of the withdrawals by the population occurred in late April and early May. In addition, during the pandemic, several failures were verified in accessing benefits and in the delay in analyzing and registering beneficiaries. Despite this, the amount of public expenditure announced is above the average for Latin American countries (World Bank, 2020).

Another program to guarantee income has been implemented by the national government, the Emergency Benefit of Maintaining Employment and Income (Benefício Emergencial para Preservação do Emprego e da Renda - BEM), Law n. 14,020 of July 2020, which covers formal low-income employees. This program establishes a proportional reduction in working hours and wages of 25%, 50% or 70%, for three months or temporary suspension of the employment contract and payment of emergency benefit for two months. The government complements the employees' income, based on the amount of unemployment insurance to which they would be entitled. For example, in the case of a 50% wage cut, the government will pay the worker 50% of the unemployment insurance to which he would be entitled. Contract suspensions, on the other hand, will last for two months, and the government will pay unemployment insurance in whole or in part, depending on the company's earnings, and the amount cannot be less than the minimum wage. Later in 2020, Decree 10,422, the government extended the period of the reduction of hours and wages and the suspension of the contract to four months. In October 2020, it was extended until December 2020.

Waltenberg, da Silva and da Silva (2020) point a number of defects of these measures in protecting employment. The employer is required to keep his job only for the same period

[10] Cadastro Único (Cadúnico), the National Government's Unique Registry for Social Programs, is an instrument to identify low-income families (monthly per capita income of up to half a minimum wage or total family income of up to three minimum wages. Minimum wage = R$ 1045.

that he received the aid. Thus, in four to six months, the worker affected by the reduction or suspension may be unemployed. In addition, as the company is exempt from paying its employer contribution to the Social Security (zeroed in the case of suspension), the worker loses the contribution amount for his future social security benefits (and contribution time in the case of suspension).

According to the monitoring of the Federal Audit Court, until July 31 2020, 12.4 million work agreements were signed, with employees receiving an average monthly benefit of R$ 863 from the Emergency Benefit of Employment and Income Preservation (BEM), having been executed R$ 18,6 billion, just over a third (36%) of the extraordinary credits approved for the program.[11] Regarding the Emergency Aid, until August 31, 67.2 million people were included, 84% receiving a benefit of R$ 600 and 16%, R$ 1,200, with a total expense of R$ 212.64 billion.[12]

Brazilian labor market was already experiencing difficulties before the pandemic. Despite the relative success of the two programs (AE and BEM) in terms of preserving income and, to a lesser extent, jobs, there was a sharp deterioration in the labor market throughout 2020. In the first months of COVID-19 there was a large outflow of people from the labor force, mainly in the informal sector, whose workers were unable to move to work, but also in the formal sector of the economy. As a result, the growth in the unemployment rate was relatively small. Subsequently, with the relaxation of social isolation measures, there was a small recovery in the economy and the return of part of the labor force, putting pressure on the unemployment rate. But perhaps the most impressive figure on the job market in the first six months of the pandemic is the reduction of 12 million employed people, from 94 to 82 million.

Moreover, the immediate effects of the COVID-19 pandemic crisis on labor income fell mainly on workers with more fragile insertions in economic activity, both in terms of employment relationship and in terms of income. The obvious consequence of these

[11] https://portal.tcu.gov.br/imprensa/noticias/mais-de-12-milhoes-de-trabalhadores-foram-beneficiados-por-programa-emergencial.htm.

[12] https://aplicacoes.mds.gov.br/sagi/vis/data3/index.php?g=2.

distinct impacts on income was an increase in labor income inequality. The Gini coefficient of effective earnings in June 2020 was 0.54, significantly higher than the Gini of the earnings normally received (0.47). In addition, the most unequal states recorded the greatest increase in inequality.

The distribution of federal public spending on measures to mitigate the effects of COVID-19 can be seen in **Table 2**. The measures described above referring to Emergency Aid for People in Vulnerable Situations and the Emergency Benefit of Maintaining Employment and Income represent 64% of the Union's expenditure prevision to fight the pandemic.

As the pandemic crisis affected the fiscal equilibrium of states and municipalities, both due to the decrease in tax revenues resulting from social isolation and the increase in spending on hospitals and social assistance, the importance of the Financial Aid to States, Municipalities and Federal District is highlighted (14 % of the total Union budget spending forecast). The measure related to Additional Expenses of the Ministry of Health and other Ministries represent 11% of the budget expenditure forecast.

These last two measures are, to some extent, related to the increase in public hospital expenses resulting from the growth of the demand for care related to Covid. Brazil has one of the largest public health systems in the world, the Unified Health System (Sistema Único de Saúde - SUS), with good capillarity in the municipalities, serving around 75% of the Brazilian population, the remaining 25% being covered by private health insurance plans (Paim et al., 2011). SUS care in basic health units and family health teams act as the gateway to the system as a whole. As it is estimated that 80% of COVID-19 cases do not progress to very severe forms of the disease, it was within the scope of these municipal services that much of the care and guidance to the population was provided. However, medium and high complexity care is an “old” problem for SUS, becoming evident in the pandemic. Rache et al. (2020) analyzes information on the number of urgence intensive care beds and ventilators by Brazilian health regions and finds evidence of enormous regional heterogeneity and scarcity of resources in most regions. The pandemic proved the scarcity of resources for health and showed inequality, not only between public and private health systems, but within SUS, as well as in the difference in the supply of urgency intensive care beds between municipalities and regions of the country.

Table 2: Federal Public Spending on COVID-19 in September 2020 (R$ billion)

Measures	Expenditure Prevision	Expenditure Payed
Emergency Aid for People in Vulnerable Situations	322,00	217,46
Financial Aid to States, Municipalities, DF	79,19	74,39
Additional Expenses of the Ministry of Health and other Ministries	65,29	35,97
Emergency Benefit of Employment and Income Preservation	51,55	24,94
Quotas of Guarantee Funds for Credit and Operations	47,90	42,90
Granting of Payroll Financing	17,00	17,00
Expansion of the Bolsa Familia Program	3,04	0,37
Transfer to Energy Development Quota	0,90	0,90
Total	586,87	413,93

Source: Tesouro Nacional Transparente. https://www.tesourotransparente.gov.br/visualizacao/painel-de-monitoramentos-dos-gastos-com-covid-19

Brazilian measures (both revenue, expenditure and financial ones, up to April 2020) corresponds to 10% of its GDP, according to IMF (2020). Brazil´s spending is lower than those of advanced countries – notably Germany, Italy, Japan and UK, but exceeds most of other developing and emerging economies.

The government's emergency income guarantee plan to deal with the pandemic crisis seems to have achieved the most vulnerable population in large numbers, with an effect on reducing inequality in household per capita income (Carvalho, 2020).[13] It is worth mentioning that the registration effort for the Emergency Aid offers a great opportunity for the necessary integration of public social policies in Brazil.[14]

[13] See also Menezes Filho, Programas sociais e finanças públicas. Valor Opinião (Acesso em 09/09/2020).

[14] Webinar IPEA on different social policy of cash transfer, comparing to Emmergencial Aid: https://www.youtube.com/watch?v=OLvwGQBTEcQ.

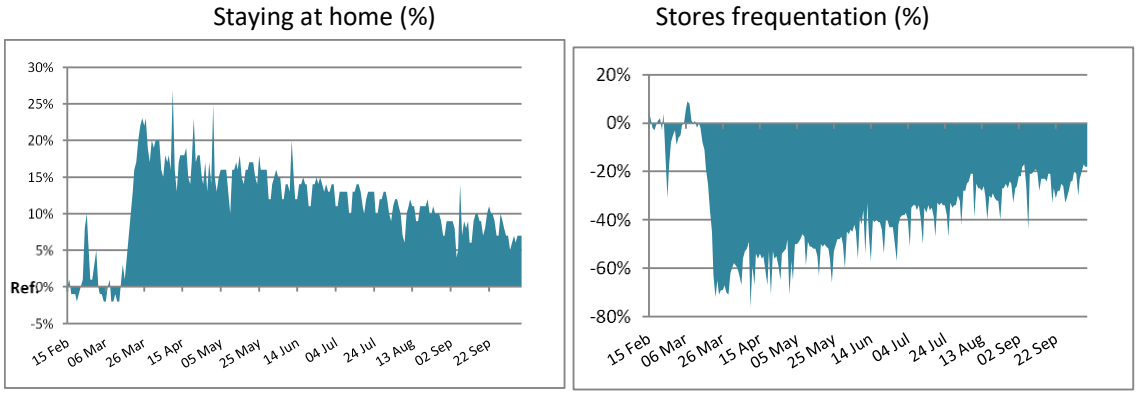
2.3 Enacted policies and effective mobility of the population

Apart from the ambiguous or even frankly hostile attitude of President Bolsonaro, all the measures, whether economic or in terms of health, have been in the direction of a more or less strict reduction in the mobility of movement of the population. However, real mobility depends not only on the policies implemented but also on the capacity of the authorities to enforce them and the degree of support of the populations to these measures. The result of these three factors is presented in **Figure 3**, from two independent sources of information: *Google Mobility data* and *Facebook Movement Range Maps*.

At the national level, the two sources give convergent results. Compared to the reference period (begining of 2020), a rapid and massive dropout can be observed between March 13 and 25. In just over a week, store visits have fallen up to 70% (*Google Dat*a). Conversely, the time spent at home increases by 20%. After this date, confinement is gradually relaxed, under the double effect of flexibilization measures and their lesser respect by the population, without however reaching the pre-pandemic level. Facebook data confirms this overall diagnosis. The profile is generally the same (**Figure 3**, right panel), but the interest here is to get an estimate of the absolute level of confinement (and not just the deviation from a reference period). Even at the time of maximum containment (end of March), only 40% of the population stayed at home all day. This rate decreases to 25% in early October, a level of barely 5 points higher than that of the pre-containment period (beginning of March).

Figure 3: Population Mobility in time of COVID-19 (15, February – 11, October 2020)

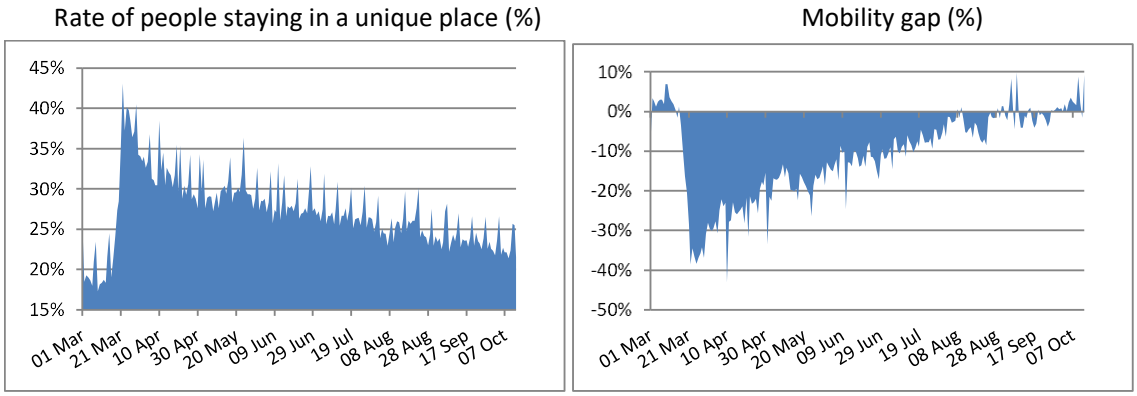
Google Data



Source: Google COVID-19 Community Mobility Reports; authors' calculations.

Note: Google Data correspond to gaps compared to a reference period (1, January – 6, February).

Facebook Data

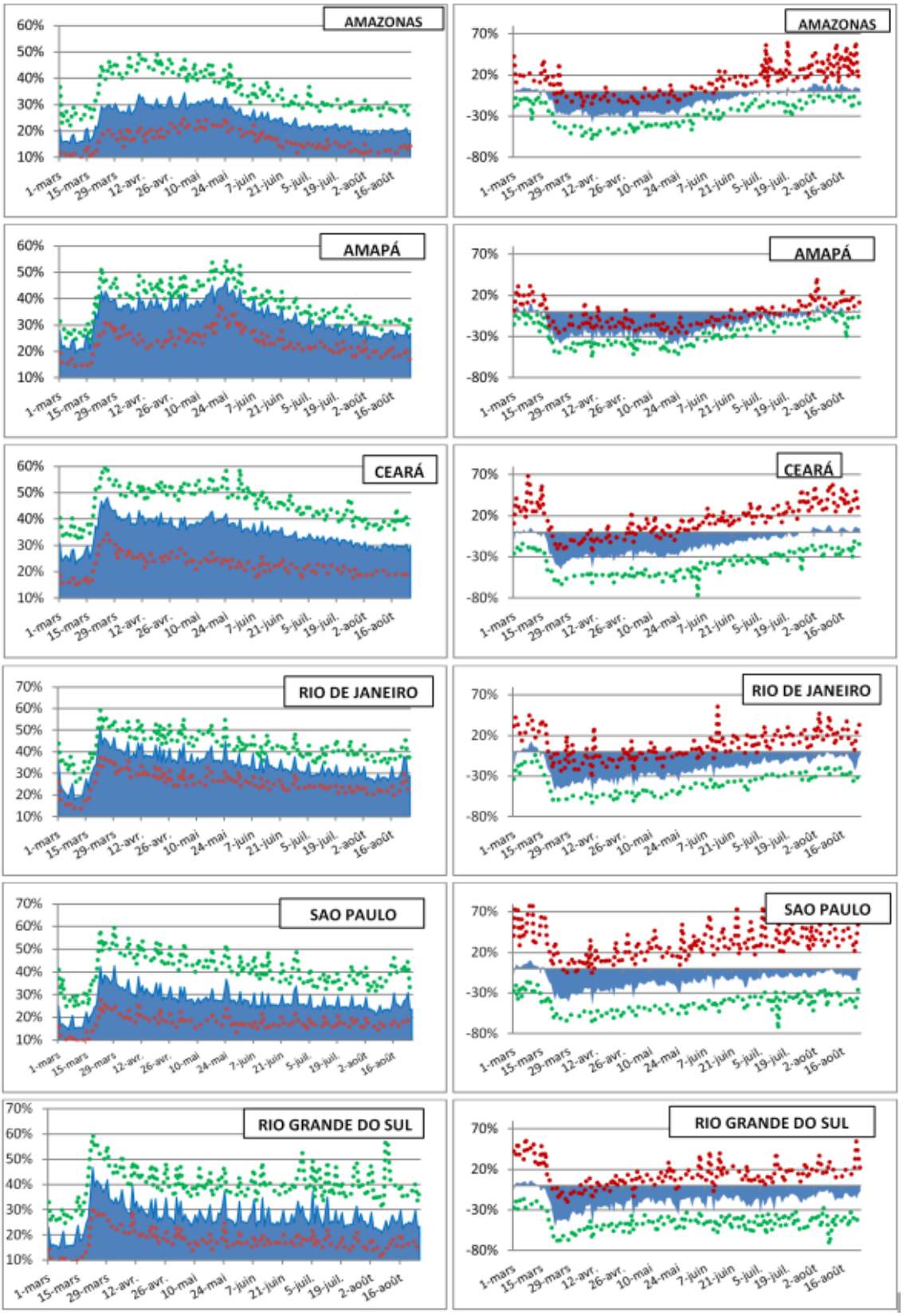


Source: *Movement range maps*, Facebook; authors' calculations.

Note: The left panel corresponds to the percentage of those who did not move during the day; The right panel, corresponds to the deviation of those who left home compared to a period of reference (February).

However, this dynamic at the national level does not reflect the differences observed at the state level, and even less at the municipal level, only available with *Facebook* data. **Figure 4** shows, as illustrative examples, the case of six states distributed in different regions. While the start of containment appears to have taken place more or less at the same time, it is applied very differently from one *município* to another. The green dotted curves correspond, day by day, to the *município* where the proportion of individuals who have stayed at home is maximum, while the red dotted curve corresponds to the *município* where the respect of the instruction is at the lowest. The gap between the two curves can be very large and varies from state to state. The models estimated in the fourth part of this paper take into account this variability.

Figure 4: Heterogeneity in the level of containment by States and *municípios*: some examples



Source: *Movement range maps*, Facebook; authors' calculations.
Note: see Figure 3. The dotted curves (red / green) are the minimum / maximum values for the *municipios* within the States.

3 Approach, data and descriptive statistics

3.1 The municipalities as units of analysis

As previously stressed, the objective of this study is to shed light on the demographic, socio-economic and political factors associated with the COVID-19 epidemic, to identify potential transmission channels, and to the extent possible to evaluate the effectiveness of certain measures at the level of Brazilian municipalities (*municipios*). Beyond descriptive statistics (unconditional correlations), we will estimate simple econometric models, mainly to take into account structural effects (conditional correlations), more than to study causal impacts.

The observation unit is the *municipio*. It is an administrative entity at the level of which mayors are elected (prefeitos). Brazil counts 5,570 *municipio*. It is the smallest administrative entity for which comprehensive national data on COVID-19 infection is available. Choosing the *municipio* level has several advantages, compared to alternative units of analysis: individual data or other levels of geographical aggregation:

- it is the only way to guarantee the exhaustiveness of all *municipios* in the country. By definition, statistical surveys are based on random samples. They include only part of the *municipios* and are not representative on this scale. For example, in the case of Brazil, the PNAD-C, the most ambitious socio-economic survey in Brazil, in spite of hundreds thousands of individual observations, does not allow smaller inference levels than the 27 States, subdivided into three groups (state capital, metropolitan area and the rest). With 74 geographic domains, it is not possible to estimate econometric models;

- still with regard to data sources, on the one hand, socio-economic surveys are often poor in health indicators, except for specific surveys. Even more crippling in the case of the pandemic, by nature they do not allow counting deaths, our main variable of interest. On the other hand, the administrative sources from the health system are poor in socio-economic descriptors, either they are not collected or they are not disclosed for medical confidentiality reasons;

- in terms of behavior, the causes and effects of the pandemic are not only the result of individual dynamics but also of collective ones. The most obvious example is the contamination process which depends on the characteristics of the *municipio*, such as the density of the habitat, the mobility of its residents, the state of its health system, etc.;

- lastly, many policies are developed and implemented at the municipal level, as shown in section 2. In Brazil, the infra-federal levels (States, *municipios*) enjoy a large share of autonomy to conduct their own policies. This specificity is particularly acute in the fight against COVID-19. Faced with the government's ambiguous attitude, each *municipio* has defined its own fight strategy (confinement, establishment's closure, barrier gestures, etc.). This confusion has resulted in great heterogeneity in the response and management of the pandemic as shown in **Figure 4.**

Despite its advantages, the *municipios* approach has a number of limitations and its results should be interpreted accordingly. A first drawback is that it is not possible to mechanically transpose its results in terms of individual risks. Take the example of income. On the one hand, if the infection (or death) rate were the same between rich and poor, then the income variable would have no influence in the models. We are therefore able to identify the factors that influence the impact of the pandemic. On the other hand, suppose that the wealthiest municipalities are the most affected (more activity, movements, interactions). This does not mean that the wealthiest people are the most affected. It may be the poorest of wealthy municipalities who are most at risk of being infected (for example because they cannot afford to comply with containment policies). This is indeed what we observe (see part IV). Nevertheless, it can be assumed that in general the individual and *municipio* approach converge.

A second characteristic of the *municipio* approach is that it treats all *municipios* on an equal footing, regardless of their demographic weight. However, the size of the Brazilian *municipios* is highly heterogeneous: from 12.3 million inhabitants in the *municipio* of São

Paulo, and 6.7 million for that of Rio, to 837 in the *municipio* of Bora (São Paulo State).[15] As a consequence, the number of contaminated people, and especially the number of deaths is itself very concentrated in the large *municipios*. One way to deal with this issue would be to go down to the district and sub-district level in the big cities. Unfortunately, COVID-19 data are not available at this level, except for a few cities (Rio or São Paulo for example). However, these differences in size are neither crippling, nor even necessarily a problem. From a legal point of view, each *municipio* has the same status vis-à-vis the law and its rights, regardless of its size. From an empirical point of view, our approach is equivalent to country regressions, very common in the economic literature (in growth econometrics for example), in spite of equally heterogeneous countries. Of course, our analysis focuses on the rate of contagion and death and not on their absolute number. Finally, the models are also estimated by weighting the observations by the size of the population, as a robustness check.

Finally, the *municipio* is the smallest administrative entity where a certain number of socio-economic data are available on an exhaustive basis, while the number of observations is sufficient to estimate econometric models. The approach is more complementary than competitive with the individual approach, the two providing different information that should be cross checked.

3.2 Empirical strategy, data and variables

In order to identify the characteristics of the *municípios* most affected by the pandemic, the death rate and the rate of confirmed cases will be modeled through a linear regression that considers three major groups of explanatory factors: first, the socio-demographic and socio-economic variables; then, variables characterizing *municípios*; finally, the policies or measures applied at this level, and their impact (see **Figure 5**). To these three blocks of independent variables, we will add control variables. These latter variables take into account, on the one hand, the fact that the pandemic did not start at the same time in the various *municípios*. On the other hand, efforts and resources mobilized to measure the

[15] A similar distribution is observed for *counties* in the US: from 75 to 10 million inhabitants (McLaren, 2020).

evolution of the pandemic (number of tests and consolidation of data from different sources) also differ according to the *municípios*.

$$Y_i = a_0 + \alpha_m^T X_i^m + \beta_n^T E_i^n + \gamma_k S_i^k + \delta_l C_i^l + u_i \qquad (1)$$

Y_i represents either the death rate or the rate of identified cases
X_i^m vector of individual socio-economic variables (of dimension m)
E_i^n vector of environmental variables at the municipal level (dimension n)
S_i^k vector of measures or policies (dimension k)
C_i^l vector of control variables (of dimension l)

The estimation will be made at different dates (5 dates from June to October), but we will focus on the result obtained in August, 11th, when we can say globally that the first wave of the pandemic was at the peak in Brasil. In parallel, we also estimated the panel model (*municípios* are monitored from one period to another) in order to better take into account the progression of the epidemic over time. The specification is thus as follows:

$$Y_{it} = a_0 + \alpha_m^T X_i^m + \beta_n^T E_i^n + \gamma_k S_{it}^k + \delta_l C_{it}^l + u_{it} \qquad (2)$$

Where

Y_{it} represents either the death rate or the rate of identified cases at t (date t)
X_i^m vector of individual socio-economic variables (of dimension m)
E_i^n vector of environmental variables at the municipal level (dimension n)
S_{it}^k vector of measures or policies (dimension k) at time t
C_{it}^l vector of control variables (of dimension l) which varies over time t

(1) The first group brings together individual variables of socio-demographic type (sex, age, skin color, education, state of health, and migratory status) and socio-economic (poverty, situation on the labor market). In addition to these classical variables, we also took into account an indicator of movement outside the *municípios* for professional reasons, a potential factor which impacts the spread of contamination. Although belonging to the same group, these variables should not be interpreted in the same way. Indeed, there are purely epidemiological reasons which explain differences according to age, for example (even if they can

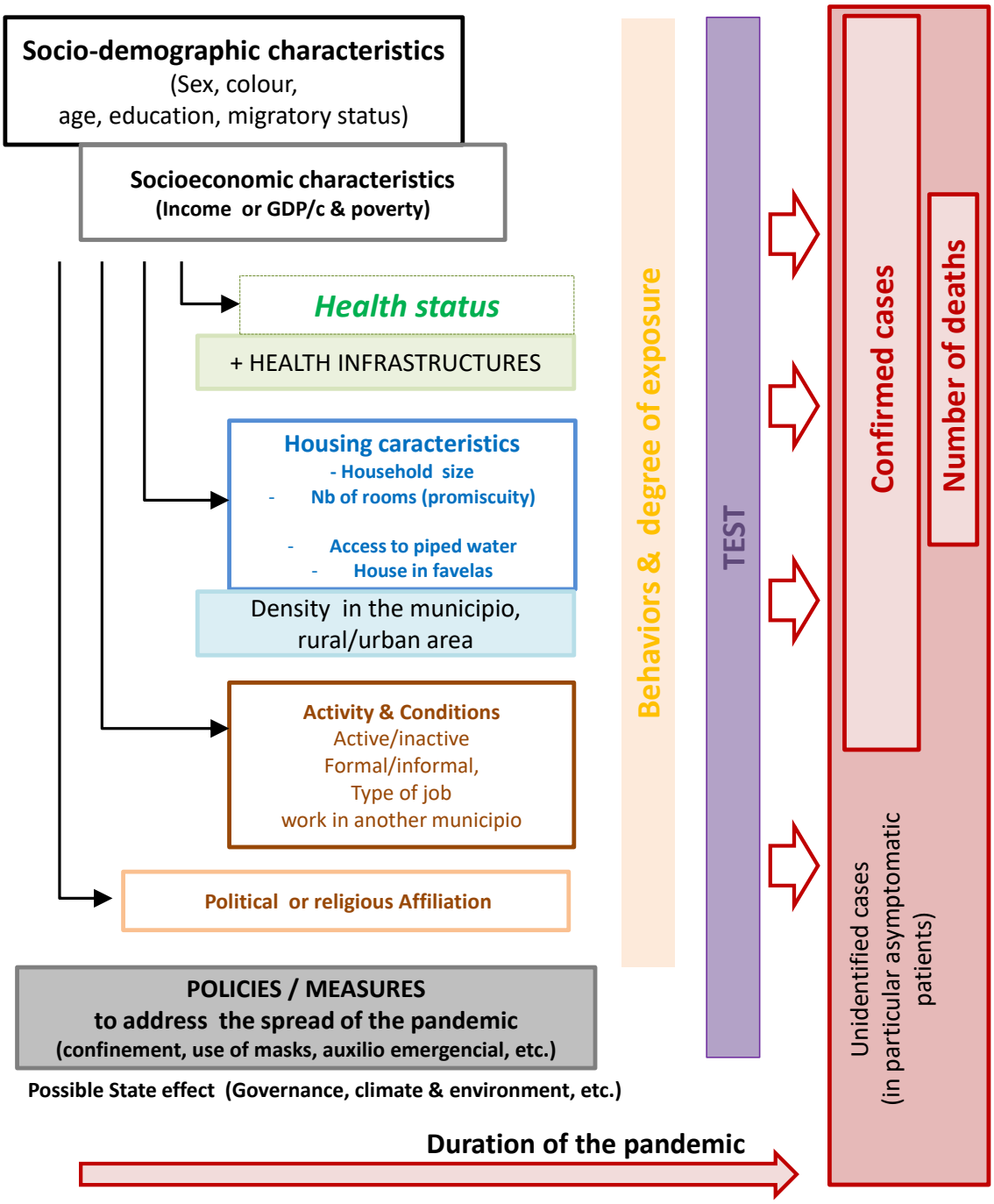
interfere with variations in behavior). But regarding the possible disparity in terms of contamination or death according to the level of education, color or migration status is due to differences in social behavior.

(2) The second group is made up of variables characterizing the *municípios*. This is the case of the level of development (GDP per capita), density, location (urban / rural), type of habitat (favela) and housing (promiscuity, access to sanitation services) and health infrastructure. The ability of individuals to avoid or cure disease depends on these characteristics.

(3) The third group includes variables reflecting certain policies implemented (directly or indirectly). We have chosen two of them. On the one hand, the percentage of supporters of President Bolsonaro, with the hypothesis that the latter are the most reluctant to respect the measures taken to contain the disease (lockdown or containment measure, hand hygiene or social distancing, use of masks, etc.). On the other hand, the date and degree of confinement, which captures both political decisions and the level of compliance in the *municípios* population.

(4) Finally, we include in the models two control variables: the duration of the epidemic and the number of tests performed. These two variables have an impact on the number of cases and deaths counted since, on the one hand, the number of deaths and accumulated cases increases with the duration of the pandemic and, on the other hand, the probability of identification of cases increases with the number of test.

Figure 5: Socio-economic factors of COVID-19: A logical framework



Source: Authors.

These different groups of factors affect the degree of exposure and the resistance of individuals, but also their behavior in response to measures taken at the *municípios* level. Our dependent variables are the number of deaths and confirmed cases from the database

of Brasil.IO (based on data from the Ministry of Health), their evolution over time, as well as all the related variables (for example, the rate of contamination among the population considered).

As we have already pointed out, the quality of these data needs to be evaluated: they are both underestimated and potentially biased (França et al., 2020; Souza et al., 2020; see below, Robustness check). As regards the number of coronavirus cases, the counting considers only those who have been tested and identified with a lab-confirmed infection. As for the number of deaths, only the hospital deaths were taken into account and by nature the identification of the causes of death is difficult to establish. This is a global problem which applies to all countries. But it is probably more acute in Brazil (in particular, regarding the number of cases) given the deficiency of the testing policy in Brazil. The fact remains that these are the only two variables available at the *municípios* level, used by all to monitor the pandemic. Apart from the strict warnings, we have sought to limit the effects of the bias or underestimation as much as possible and to discuss the results in the light of their potential impact.

We will try to control the impact of this bias on our results by mobilizing the test rate carried out on the population, rate which varies depending on the municipality. However, we can discuss to what extent this control is relevant: if the variation of the test rate is not random but depends on the infection rate, in this case, the test rate should not be used for the correction. This hypothesis deserves to be considered because indeed it is mainly the persons who present symptoms who are tested and it can be assumed that the asymptomatic rate does not vary between municipalities. Obviously, the reality lies between the two extreme cases: a test rate completely independent of the different variables used and a test rate completely linked to the level of infection. The solution considered is then to control by the test rate available at the state level, and we will assume that within each state, the test rate varies according to the infection rate between municipalities.

Our independent socio-demographic variables at the individual level are firstly taken from the last population census carried out in 2010 (PC2010). The main advantages of this source are a) its exhaustivity (it provides measurements without sampling error) and b) the wealth of information collected. From this point of view, the PC2010 is exceptional,

including when compared to other countries. Alongside the usual socio-demographic variables in censuses (sex, age, education, migration), a labor-income module was inserted into the questionnaire for a representative sample of all households, accounting for around 1/10th of the entire population of the country (IBGE, 2012). In addition, the IBGE provides the database in open access. We therefore processed the micro-data on this 1/10th sample with more than 20 million individual observations. On the other hand, the main weakness of the PC2010 is its age: some characteristics of the *municípios* might have changed since 2010. Nevertheless, the robustness tests of our results using different strategies show that this problem is very circumscribed (see part IV.2 below).

Apart from the PC2010, ten other types of data were used:

- Information from the MUNIC survey (IBGE, 2018). This survey, carried out every year at the *municípios* level, collects information on the structure, functioning of public institutions and the administrative capacities of the *municípios*.

- The GDP of each *municípios* in 2017 provided by IBGE.

- The population and density (estimated in 2019) by IBGE.

- The characteristics of the health system (number of beds, doctors; IBGE-health 2019).

- The percentage of houses in favelas (IBGE, *agglomerados subnormais*, 2019, preliminary results of the 2021 census).

- The average life expectancy per *município*, as a synthetic indicator of the state of health of the population, taken from the FIRJAN municipal development index. Its components also allow for robustness tests by providing alternative measures in terms of health, education and employment / income.

- The results of the 2018 presidential election for political factors (TSE, Tribunal Superior Eleitoral).

- Data on tests (Ministério da Saúde e Secretárias Estaduais / Fiocruz).[16]

- *Facebook* data on the mobility rate and the rate of people staying at home (for cities for which we have no data, we considered the average at the state level). These data are used to assess the level of confinement in each *município* and above all to identify from when the social distanciation measures have been effectively applied (and the level of compliance). We used Facebook data rather than other sources (such as Google for example) because they are the ones that provide detailed data by *municípios* with the widest coverage (3,327 *municípios* spread across the 27 states).

- Data on the number of beneficiaries of the *Auxilio Emergencial*[17] which makes it possible, on the one hand, to identify municipalities with a high rate of poverty and, on the other hand, to measure whether this measure has made it possible to limit the spread of the virus allowing individuals to respect the confinement.

With the exception of a few variables that directly characterize *municípios* (GDP, density, etc.), all the indicators calculated are averages per *municípios*.

3.3 Descriptive Statistics

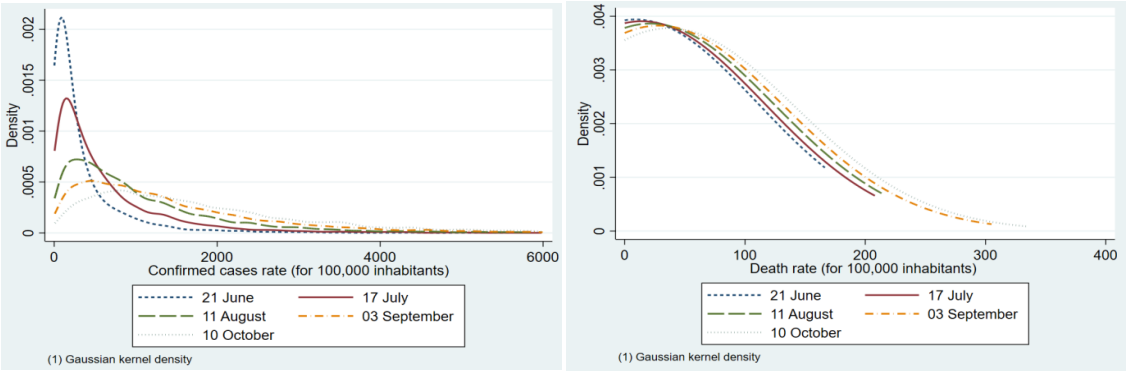
As of August 11, the average infection and fatality rates per *municipios* were 1,081 and 23 per 100,000 inhabitants respectively. They are characterized by a huge dispersion (**Figure 6**), with a minimum of 6 and a maximum of 15,730 for the infection rate, and 0 and 213 for the fatality rate. At this date (11/08), 1,766 *municipios* had no recorded deaths). Beyond the intensity of the epidemic, the *municipios* were affected and reacted on very different dates (**Table 3**). For example, as of August 11, depending on the location

[16] Data available through the Brasil painel, https://covid19br.wcota.me/ (Cota, 2020).

[17] Data were extracted from the website (http://www.portaldatransparencia.gov.br) which provided rough exhaustive data for 4 months (April – mid July). Files, with data on up to 59 million of individuals in May, were processed (Caixa Econômica Federal, INSS-BPC). Given the eligibility criteria to allocate the *Auxilio Emergencial* (see section II-2), the percentage of beneficiaries is the best proxy of 2020 (relative) poverty headcount at municipal level.

24 to 164 days had passed since the outbreak of the epidemic. As for containment, some *municipios* put it in place up to four months before the appearance of the first confirmed case, while others let three months pass before reacting. The test rate is itself very variable from one state to another, with a difference of 1 to 9 (with 1,756 tests per 100,000 inhabitants for the State of Mato Grosso and 15,112 for the Federal District).

Figure 6: Distribution of confirmed cases and fatality rates by *municipios* (100,000; Kernel density)



Source: Ministry of Health/Fiocruz; authors'calculations.

Beyond the size and COVID-19 infection rates, the socioeconomic composition of *municipios* is also highly heterogeneous (**Table 3**). This is particularly the case for our main variables of interest. The share of white people in the population extends over a broad spectrum with a minimum of less than 1% to a maximum of 96%. Poverty (proxied by the percentage of beneficiary of the Auxilio Emergencial) varies from 4% to 80%, the informal employment share from 10% to 64% and voting rate for the candidate Bolsonaro in the 1st round of the 2018 presidential election from 2% to 84%. Even the sex ratio ranges from 46% to 59%.

Table 3: Descriptive Statistics

%	Average	Standard Deviaiton	Min	Max	Source
COVID-19					
Confirmed case rate	1,081	1,130	6	15,730	Min Saude/IO
Fatality rate	23	26	0	213	Min Saude/IO

Test rate (State level)	4,021	1,488	1,756	15,112	Min Saude/Fiocruz
Nbr. days (since 1st case)	87	30	24	164	Min Saude/IO
Socio-demographic					
Sex (Male)	50.5%	1.4%	45.8%	58.9%	CENSO 2010
Age (average)	32.2	3.2	19.9	44.3	CENSO 2010
Education (tertiary)	3.6%	2.3%	0.1%	23.9%	CENSO 2010
Race (white)	46.7%	24.1%	0.7%	99.6%	CENSO 2010
Life expectancy	73.1	2.7	65.3	78.6	FIRJAN
Migration	39.4%	16.1%	4.8%	96.4%	CENSO 2010
Socio-economic and Labor market					
GDP per capita	21,991	20,946	3,285	344,847	IBGE 2018
Poverty *(Aux Emerg)*	21.7%	6.8%	4.0%	80.4%	INSS-BPC
Informal worker	10.9%	3.7%	2.2%	31.4%	CENSO 2010
Work travels	5.3%	4.7%	0.0%	32.5%	CENSO 2010
Socio-politic					
Vote Bolsonaro 1st 2018	38.7%	19.0%	1.9%	83.9%	TSE 2018
Evangelist	17.1%	9.5%	0.4%	85.8%	CENSO 2010
Density and housing					
Density	108.2	572.4	0.13	13204.6	IBGE 2019
Rural	35.5%	21.3%	0.0%	95.5%	CENSO 2010
Favela	1.0%	4.5%	0.0%	74.0%	IBGE 2019
Access to water (no)	9.2%	12.8%	0.0%	85.4%	CENSO 2010
Nbr. persons/room	0.7	0.16	0.42	2.09	CENSO 2010
Health System					
SUS_hospital	47.2%	49.9%	0.0%	100.0%	MUNIC 2017
Sanitary Vigilance	98.4%	12.6%	0.0%	100.0%	MUNIC 2017

Nbr. Doctors/100k	82%k	83.6%k	0%k	277%k	IBGE-health2019
Nbr. UTI beds/100k	2.25%k	9.2%k	0%k	228%k	IBGE-health2019
Mobility/confinement					
Nbr. Days without confine. /(since 1stcase)	-29,3	23,5	-127	93	Facebook

Sources: Ministry of Health, IBGE, TSE, INSS-BPC, Facebook; authors' calculations.

The simple correlations provide a first glimpse of the links between infection and death rates with the variables retained in the analysis (**Table 4**). As expected, the contamination rate depends on the test rate and the number of epidemic days in absolute terms and without containment (0.32, 0.31 and 0.20). It also depends on the rate of promiscuity in dwellings (0.36), and on the part of the population living in the favelas (0.17). Contrary to intuition, it is negatively related to age (-0.36): the more young people there are in the *municipio*, the more the disease rages. Of all the socio-demographic variables, the strongest correlation is observed for race (-0.22 for the proportion of whites in the *municipio*). The contamination rate is also a function of the poverty, with a correlation of 0.17.

Regarding the mortality rate, the correlations are generally of the same order of magnitude as for the contamination rate: positive with the test rate, the number of days since the identification of the first case and the number of days without confinement, overcrowding in housing, favelas, and poverty; negative with the proportion of white people, life expectancy and the rate of informality. Among the most notable differences, mortality is an increasing function of age (0.25). Mortality increases with density (0.22), as does job related travel outside the *municipio*. The *municipios* with a higher proportion of women are also more affected. Finally, on the political front, the share of the president's supporters does not correlate with mortality, while it tends to lower the rate of infection.

Table 4: Main variables correlations

Variables	Confirmed Case	Fatality
COVID-19 (11 August)		
Fatality Rate	+0.512***	-
Test (State level)	+0.308***	+0.172***
Nbr. days since 1st case	+0.316***	+0.399***
Socio-demographic		
Sex (Male)	+0.030	-0.114***
Age (average)	-0.348***	-0.247***
Education (<=primary)	+0.050***	-0.061***
Education (tertiary)	-0.073***	+0.005
Race (white)	-0.221***	-0.186***
Migration	+0.024	+0.028
Socio-politic		
Vote Bolsonaro (1st round)	-0.058***	-0.027
Evangelists	+0.122***	+0.177***
Density/Housing		
Density	+0.037***	+0.205***
Rural	-0.039***	-0.138***
Favela	+0.171***	+0.303***
Promiscuity (house)	+0.377***	+0.262***
Socio-economic & Labor Market		
GDP per capita	+0.026	+0.022
Gini	+0.223***	+0.169***
Informal Employee	+0.034	-0.006
Own Account Worker	+0.065***	-0.030
Inactive	+0.098***	+0.076***
Primary	-0.105***	-0.151***
Service	-0.034	+0.101***
Administration	+0.076***	+0.010
Work mobility	-0.020	+0.116***
Auxilio Emergencial	+0.168***	+0.152***
Health		
Access to water (no)	+0.251***	+0.159***
Life Expectancy	-0.162***	-0.113***
SUS Hospital	+0.149***	+0.150*
Nb. doctors/100k	+0.026	+0.080***
Nb. UTI beds/100k	+0.049***	+0.114***
Nb days without confinement	+0.129***	+0.214***
Informal Worker	-0.053***	-0.080***

Sources: Ministry of Health, IBGE, Facebook; Authors' calculations.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

The socio-economic characteristics are themselves highly correlated with each other, in the expected direction, and often at much higher levels. First, the share of the white population increases with higher education (0.52), the *municipio* development (0.59), life expectancy (0.66), and age (0.70). On the political front, the share of whites increases with the vote in favour of Bolsonaro (0.69). These correlations between socio-economic variables are particularly important for our study. Indeed, the simple correlations between COVID-19 indicators and these variables could ultimately only reflect structural effects. For example, the "white effect" may only be due to the fact that white people are on average richer, more educated and in better health. It is precisely to dispel this ambiguity that the econometric models presented in the following section attempt to identify the specific effect of each factor, that is, once the effects of the other variables have been controled.

4 Results and discussion

4.1 The basic model (August 11 2020)

The results of the basic model using OLS method are shown in Table 5. We will comment the results by block of variables , focusing on the analysis of the mortality rate . Reading the different models, from the simplest to the most complete, allows to assess the robustness of the effects.

Demographic, economic and political indicators: these constitute our main variables of interest, with the main objective to identify the main social groups at risk.

Age: as expected, the municipios where the population is on average older are more severely affected in terms of deaths. This result is in line with the epidemiological factors aggravating the disease. This is also a good illustration of the value of our approach by regressions (all things being equal), since it is in municipios with the youngest inhabitants that the mortality rate is the highest (Table 4). On the other hand, the older the average age in a municipio, the fewer confirmed cases there are. The models showing the evolution of the factors of the pandemic over time presented below (section IV-2) show that initially this was not the case neither in June nor in July (coefficients not significant). This change is compatible with the dynamics of the pandemic which increasingly affects young people, even if they are more often asymptomatic.

Sex: the gender effect on the death rate (and confirmed cases) is not robust. In the full models, it tends to increase with the proportion of men in the municipio (coefficients not always significant). Here too, the regression approach shows all its interest since the relation is negative according to the simple correlations. This result could be the combination of epidemiological factors and social behaviors (Griffith et al., 2020), with men tending to engage in more risky behaviors than women in general.

Education: the effect of higher education level is negative, on the mortality and especially on confirmed cases. It is all the more robust that this effect is a priori underestimated, the more educated going to be tested more often (cf. PNAD-Covid,

August 2020). One can suggest that this effect is due to better access to information and more careful behaviours.

Health status and health infrastructure: logically, the average life expectancy, which can be interpreted as an indicator of global health status, reduces the probability of death in the municipality, but has no effect on the contamination rate. Health infrastructures as captured by the available indicators (presence of an SUS hospital, rate of medical staff, number of beds) has little effect on the presence of the disease. The only significant factor is the number of doctors which plays on the contamination rate, and the effect is positive. We can assume that medical coverage induces the population to consult, including for less serious symptoms, and therefore increases the number of detected cases (even if the models partially controls for the test rate; see below). Other studies find this same effect and provide another possible explanation: along with the positive effect of better patient care, globally, the medical staff, on the front line, was confronted with the disease and suffered in first instance of its disastrous consequences (McLaren, 2020). But it should also be stressed that the most affected cities (generally the biggest) are also those with relatively more healthcare professionals. Last, it should be noted that the development of health infrastructure does not seem to have an impact on mortality.

Race: The municipios with more white population are more likely to be spared, both in terms of confirmed cases and death. This is the most significant and robust effect of our regressions. 1 percentage point (ppt) supplement of white people in the municipio, decreases the number of deaths by 1.83 per 1 million people and by 52.8 the number of confirmed cases (per million). This effect is all the more remarkable since it adds to the other aggravating factors taken into account by the models from which non-white populations also suffer: a lower level of education, higher poverty rate, higher informal economy and more degraded housing conditions (residence in favelas and in conditions of greater promiscuity, less access to public sanitation services), etc. Our result confirms and goes beyond those obtained in other studies using different approaches: whether the simple correlations of Batista et al. (2020) or Polis (2020) for the districts of São Paulo municipio, or more sophisticated studies on individual data, such as Baqui et al. (2020) on the number of deaths in hospitals (controlled by age and region), or Hallal et al (2020) on infections from serological tests in the general population. Similar results are found in

a growing number of studies in other countries (see, for example, for the US, McLaren, 2020).

Socio-political indicator: all things being equal, the municipios where Bolsonaro obtained his best scores during the 2018 presidential election are also more affected. 1 additional ppt vote for the president in the municipio, increases the death toll by 2.8 per million people and by more than 120 the number of confirmed cases (per million). This result reverses the initial correlation (pro Bolsonaro municipios were less affected). This change comes from the specific profile of the president's supporters: less poor, more educated and more often white (Gomes de Souza, 2019; Rennó, 2020). It can be explained by the president's statements (uma gripezinha) and attitudes (walkabouts, participation in demonstrations, disregarding mask as a protection) aimed at minimizing the pandemic. As a consequence, his supporters are encouraged not to respect (or less) measures aimed at countering the disease. This phenomenon only holds for the results of the 1st round of the election. It suggests that the most risky behavior is concentrated on the hard core of the president's supporters. Our results are in line with other studies based on quasi-experimental approaches (Argentieri Mariani et al., 2020; Ajzenman et al., 2020). In the same vein, several papers show that Republican supporters less often respect social distancing measures in the US (Allcott et al., 2020; Painter and Qiu, 2020).

Socio-economic indicators and labor market:

Economic development and poverty: the most developed municipios are those with the highest rates of contamination and mortality. Indeed, the epidemic started in big cities (the first cases being recorded in São Paulo). The spread was also the fastest due to social interactions intensity (exchanges, population movements, diversity of economic and social activities). On the other hand, the poorer the municipio, the more affected (mortality and confirmed cases). This result is consistent with a growing number of studies in other countries (Brandily et al., 2020). In Brazil, Hallal et al. (2020) shows that in July 2020, the prevalence of COVID-19 estimated from large-scale serological tests varied from single to double depending on the level of household wealth: from 1.8% for the poorest quintile to 3.7% for the richest. Furthermore, as the poverty effect holds controling for GDP per capita, we highlight that the greater the inequalities, the higher the rate of contamination and mortality.

Labor market: the models show that the municipios where the share of informal jobs is highest are the ones with the most widespread contamination and mortality rate. This is especially true for the own account workers (conta próprias) and to a lesser extent for the informal employees (empregados sem carteira assinada). This effect is not a disguised income effect, since the model controls for income. One of the possible explanations is that informal jobs are more exposed (entregadores, itinerants, posts in the street, interactions with clients, reduced possibilities for teleworking). Another explanation is that without access to social security, informal workers are forced to continue working, with a greater risk of infection (for themselves and others). However, when the two variables (poverty and informality) are interacted, the coefficient becomes negative. One possible interpretation is that the informal were able to reduce their movements structurally higher, thanks in particular to the Auxilio emergencial. The latter would have had, in addition to its economic impact of protecting the most vulnerable, a health impact by making confinement at home easier to support financially, and goods (hydro-alcoholic gel ...) and health services (medical consultations) more accessible.

All of these results are all the more remarkable in that they are obtained, all other things equal, in particular by controlling density and mobility indicators within the municipios, which we show that they are clear vectors of diffusion of COVID-19.

Density and housing conditions: as expected, they are positively linked to the spread of the virus. We identify a double effect. On the one hand, the rate of confirmed cases and death increases with the population density within the municipio (robust and very significant). On the other hand, the coefficient of overcrowding in housing is an aggravating factor of the epidemic (highly significant). This result is also found for the death rate in France (Brandilly et al., 2020). Living in rural areas also lowers the rate of death and confirmed cases. This is of course an indicator of density, but the fact that the coefficient remains significant at constant municipal density can be interpreted in two ways: on the one hand, social interactions are structurally weaker in the countryside; on the other hand, since rural areas are less tested, it would improve the correction of the corresponding bias. In urban areas, the proportion of people living in favelas increases the impact of COVID-19. This effect goes beyond their socio-economic profile (poverty, health status, etc.), housing density and overcrowded dwellings, since these factors have

been taken into account elsewhere (see below). Neither is the « favela effect » a desguised effect of a lack of access to water and sanitation. Indeed, lack of access to water and sanitation has a negative effect on the contamination rate (but not on mortality). Difficulties in maintaining a sufficient level of hygiene (primarily being able to wash hands at home with clean water) is clearly an aggravating factor. We can therefore assume that the lack of access to basic services (excluding water services) penalizes municipios with a significant presence of favelas. The remarkable reaction of the inhabitants and associations working in the favelas (Fiocruz, 2020) has not been sufficient to cancel out the deleterious effects of years of underinvestment by the State in these neighbourhoods.

Mobility Indicators: as expected, they are positively correlated with the virus diffusion. The more mobile are the inhabitants of a municipio, the highest the rate of confirmed cases. This effect is particularly robust concerning the effective confinement of municipios: the greater the time lag between the day of identification of the first case and the application by the population of containment measures, the greater the contamination rates. This is also the case in the municipios where workers have to travel outside the municipios to reach their workplace (full model).

Epidemic controls: in accordance with the assumptions presented above, all other things being equal, the rate of confirmed cases and the rate of death are positively correlated with the rates of testing and the number of days since the registration of the 1st confirmed case. The extent of the pandemic of course depends mechanically on the start date of the pandemic.

Table 5: Associated factors with COVID19 mortality (for 100,000 inhabitants; OLS)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
White	-18.21****	-20.81****		-22.35****	-13.15****	-14.76****	-11.90****	-18.17****	-18.25****
(%)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sex (Male)		-36.84		-62.00**	-109.0****	124.6****	72.07**	41.52	59.82*
(%)		(0.147)		(0.020)	(0.000)	(0.000)	(0.032)	(0.218)	(0.077)
Tertiary education		47.29***		-6.534	-2.276	-59.07**	-47.67*	-66.36***	-44.45*
(%)		(0.008)		(0.750)	(0.922)	(0.025)	(0.064)	(0.010)	(0.085)
GDP/head			4.825****	6.889****	5.960****	6.297****	6.793****	5.976****	6.301****
(log)			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Auxilio (Poverty)			86.58****	41.26****	47.13****	51.01****	46.44****	56.99****	167.0****
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age					-35.74****	-31.34****	36.93****	39.11****	28.80****
(log)					(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Life expectancy	23.78	12.30	-7.670	-40.86***	-38.91**
(log)	(0.126)	(0.428)	(0.619)	(0.010)	(0.013)
Nbr. Doctors	0.00796	0.00288	-0.000522	-0.00165	-0.000999
(100 000 habitants)	(0.101)	(0.555)	(0.913)	(0.727)	(0.833)
Density		3.087****	2.510****	2.606****	2.794****
(log)		(0.000)	(0.000)	(0.000)	(0.000)
Area (Rural)		-10.20****	-11.37****	-8.948****	-12.60****
(%)		(0.000)	(0.000)	(0.000)	(0.000)
Migration		0.272	5.903**	-0.730	-1.532
(%)		(0.919)	(0.026)	(0.791)	(0.576)
Work mobility		8.090**	4.176	4.444	7.855**
(%)		(0.033)	(0.261)	(0.228)	(0.048)
Promiscuity			39.03****	38.86****	36.30****
(%)			(0.000)	(0.000)	(0.000)

Water access (No)							2.193	3.026	3.544
(%)							(0.570)	(0.429)	(0.353)
Favela							89.33****	82.71****	75.91****
(%)							(0.000)	(0.000)	(0.000)
Vote Bolsonaro								28.25****	27.48****
(%)								(0.000)	(0.000)
Nbr days without meas								0.0778****	0.0732****
(log)								(0.000)	(0.000)
Informal worker									88.35****
(%)									(0.000)
Poverty*Informal									-348.9****
									(0.000)
Test	0.00169****	0.00175****	0.00151****	0.00179****	0.00165****	0.00185****	0.00138****	0.00151****	0.00162****
(for 100 000 inhab.)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Nbr days pandemic	22.73****	21.75****	25.57****	23.96****	21.48****	17.71****	15.74****	12.30****	12.37****
(log)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-75.79****	-53.62****	-162.2****	-124.6****	-64.75	-141.4**	-245.4****	-78.37	-92.37
	(0.000)	(0.000)	(0.000)	(0.000)	(0.328)	(0.034)	(0.000)	(0.269)	(0.195)
N	5497	5487	5356	5341	5341	5272	5270	5269	5269
R^2	0.177	0.179	0.170	0.188	0.196	0.212	0.250	0.263	0.268
adj. R^2	0.176	0.178	0.170	0.187	0.195	0.210	0.248	0.260	0.265
AIC	50550.5	50453.6	49335.2	49088.4	49043.9	48176.9	47906.9	47812.4	47779.2

Sources: Ministry of Health, IBGE, Facebook; authors' calculations.

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

To get an idea of the orders of magnitude of the effects, we simulated a 10 percentage points (ppts) increase for our four main variables of interest (branco, poverty, informality and "Bolsonaro"), in two cases: at the mean; and by way of illustration, by comparing two large size well known *municipios* contrasted from the point of view of each variable considered. As **Table 6** suggests, the size of the effects is far from negligible.[18] For the branco effect, an increase of 10 ppts in the proportion of brancos in a *municipio* decreases the mortality rate per 100,000 inhabitants by 1.83, corresponding to a 8% decrease of the average rate per municipio (23). As for the number of covid cases, the decrease would be 5% of the average infection rate (1,081 / 100,000 inhabitants). If we now compare the two capital cities of Salvador (Bahia State) and Florianopolis (Santa Catarina State), whose proportion of *brancos* differs hugely (19% and 85% respectively), 347 lives would have been saved out of the 2,003 actually observed in Salvador, i.e. a decrease of -19%, if Salvador had counted the same proportion of *brancos* as Florianopolis.

Table 6: Size of the main effects (race, poverty, informality and "Bolsonaro")

(Two types of simulations: for a 10 ppts increase of each variable at the mean; by comparing two *municipios* and applying the characteristics of the second to the first; 11 August 2020)

	Distri-Bution of the variable	Simu-lation (+ppt)	**Fatalities**			**Confirmed Cases**		
			Mor-Tality rate/100k	**Simulation Results**		Infection Rate /100k	**Simulation Results**	
				ΔMorta-lity rate	**ΔM rate/ M rate**		**ΔInfec-tion rate**	**ΔInf rate/ Inf. Rate**
Branco	*Branco*							
Mean (Brasil)	47%	+10	23	-1.83	**-8%**	1,081	-53	**-5%**
Salvador (BA)	19%	+66	2,003	-347	**-19%**	62,569	-10,010	**-16%**
vs. Florianopolis (SC)	85%							
Poverty	*Poverty*							
Mean (Brasil)	22%	+10	23	+17	**+73%**	1,081	+567	**+52%**
Porto Alegre (RGS)	13%	+8	453	+198	**+44%**	9,944	+6,727	**+68%**
vs. Fortaleza (Ceara)	21%							

[18] See also in the appendix the figure A1 for other simulations.

Informality	*Informality*							
Mean (Brasil)	31%	+10	23	+8.84	**+38%**	1,081	+313	**+29%**
Campinas (SP)	19%	+15	775	+169	**+20%**	19,792	+ 5,619	**+28%**
vs. Belém (Pará)	34%							
Informality*_Auxilio_	*Auxilio*							
Mean (Brasil)	22%	+10	23	-3.49	**-15%**	1,081	-123	**-11%**
Campinas (SP)	14%	+9	775	-56	**-7%**	19,792	-1,986	**-10%**
vs. Belém (Pará)	23%							
Bolsonaro	*Bolsonaro*							
Mean (Brasil)	39%	+10	23	+2.75	**+12%**	1,081	+120	**+11%**
Salvador (BA)	28%	+30	2,003	+237	**+12%**	62,569	+10,375	**+17%**
vs. Rio de Janeiro (RJ))	58%							

Sources: Ministry of Health, IBGE, Facebook; authors' calculations.

The effects are even greater regarding the poverty impact: on average, + 73% more deaths for an increase of 10 ppts in the poverty rate. The equivalent figure for the number of cases is + 52%. If Porto Alegre (capital of Rio Grande do Sul State) had the same poverty rate as Fortaleza (capital of the state of Ceará), i.e. 24% instead of 13%, it would have recorded 198 additional deaths. Compared to the 453 registered fatalities in Porto Alegre, the increase is 44%. In number of confirmed cases, the growth is 68%. The "Bolsonaro" effect meanwhile leads to 12% more deaths for both simulations: first, on average for a 10 ppts increase and second, if Salvador, which registers only 28% of votes in favour of the president in 2018, would have voted the same way as Rio de Janeiro (58%).

Finally, informality in the labor market increases the number of deaths by 38% on average (for 10 ppts more informal jobs) and by 20% when comparing Campinas (São Paulo) to Belém (Pará). As for the informality*_Auxilio_ cross effect, which shows that the deleterious effect of informality is partially compensated by the *Auxilio emergencial*, it is also significant. For the same couple of cities, 56 lives could have been saved if Campinas had had the same proportion of *Auxilio emergencial* beneficiaries as Belém. This protective effect of the *Auxilio emergencial* amounts to 33% of the 169 additional deaths caused by the 15 ppts of informality rate that separate Belém from Campinas (34% vs. 19%), or 7% of the total number of deaths recorded in this city.

4.2 Time Dynamics

To go further, we estimated the full model at five different dates: on June 21 when the milestone of one million confirmed cases was crossed, on July 17 when that of 2 million was reached, on August 11 corresponding to 3 million, on September 3, with 4 million of cases, and finally on October 11, with 5 million cases. The corresponding figures for the number of deaths are 50,000, 75,000, 100,000, 125,000 and 150,000.[19] These estimates make it possible both to test the robustness of the results but also to monitor the evolution of the pandemic over time. On the first point, while some coefficients vary from one period to the other, in their great majority they retain their sign and their level of significance. The models are therefore very robust, the different factors always playing in the same direction throughout the pandemic.

Regarding the evolution of COVID-19 between June and October, some coefficients increase more rapidly than mortality and contamination, highlighting an increase in the effects of the variables over time (**Table 7**). This is particularly the case with our four main variables of interest. At the five dates, an increase in the proportion of whites by 10 percentage points reduces the death rate from 0.7 people per 100,000 inhabitants on average in June, to 1.2, 1.8., 2.2 and 3.1 people in July, August, September and October respectively, the color of skin becoming more and more discriminating to protect against COVID-19. Symmetrically, the aggravating effect of the political preference for President Bolsonaro continues to grow. A 10 ppts increase in the vote in favor of Bolsonaro translates into 0.7, 1.3, 2.7, 3.4 and 4.5 additional deaths for every 100,000 inhabitants. The effects of poverty and informality rates are also on the rise (between June and July, then between August and September). In August, 10 ppts of poverty at the *municipio* level generated 16.7 additional deaths (per 100,000 inhabitants). By early September, this rate had risen to 21.2. For informality, the corresponding figures were 8.8 and 10.9

[19] The precise figures are: 1,085,038; 2,046,328; 3,109,630; 4,041,638 and 5,094,979 for the number of confirmed cases; and 50,617; 77,851; 103,026; 124,614 and 150,488 for the number of deaths (sources: Secretarias Estaduais de Saúde).

respectively. At the same time, the protective effect of the *Auxilio emergencial* for informal workers seems to be increasingly effective.

The dynamics of the other variables are more contrasted. Thus, while life expectancy, seen as a proxy for health status, is a protective factor on all five dates, its impact increased until August, decelerated in September and increased again in October. Conversely, work trips outside the *municipio* have an increasingly negative impact regarding mortality rate, probably in connection with the deconfinement measures. Likewise, excess mortality in the *municipio* with larger number of men increased significantly in September (11 deaths per 100,000 inhabitants for a 10ppts increase in the sex ratio); which could be interpreted as a stronger resumption of risky behavior. The density acceleration effect only plays out until July, a likely sign of the observed spread of COVID-19 to less developed *municipios*. Most of the other variables still operate with significant coeficients, but no clear change can be noticed over time in the magnitude of the effects: this is the case for age (for the oldest), per capita GDP, the rate of residence in the favelas, and the rate of housing promiscuity. Finally, the protective effect of a higher level of education decreases until it becomes insignificant in September.

Table 7: Evolution of the factors associated with mortality rate over time (100,000 inhabitants)

	Death (date)									
	50,000 (June 21)		**75,000** (July 17)		**100,000** (August 11)		**125,000** (September 3)		**150,000** (October 11)	
Race (White)	-6.8	****	**-12.2**	****	**-18.3**	****	**-22.3**	****	**-31.2**	****
Sex (Male)	60.6	***	57.2	**	59.8	*	**110.1**	***	125.2	***
Tertiary education	-29.3	*	**-49.5**	**	-44.5	*	-33.3	ns	-22.3	Ns
GDP/cap (log)	3.6	****	5.5	****	6.3	****	7.4	****	8.1	****
Poverty (AE)	76.2	****	**137.7**	****	167.0	****	**212.4**	****	258.3	****
Age (log)	34.1	****	35.5	****	28.8	****	38.1	****	**68.1**	****
Life Expectancy (log)	-9.8	ns	**-23.5**	*	**-38.9**	**	-36.8	**	**-54.8**	****
Nb. Doctors (100 000 h)	0.0	*	0.0	ns	0.0	ns	0.0	ns	0.0	Ns
Density (log)	1.4	****	**2.6**	****	2.8	****	3.4	****	3.2	****
Area (Rural)	-8.5	****	-12.4	****	-12.6	****	**-17.7**	****	**-25.3**	****

Migration	-3.2	*	-2.3	ns	-1.5	ns	-0.7	ns	2.3	Ns
Work Mobility	3.6	ns	3.6	ns	**7.9**	*	**11.5**	**	**15.1**	****
Promiscuity	32.0	****	37.7	****	36.3	****	36.5	****	43.0	****
No Water Access	8.7	****	8.0	***	3.5	ns	1.8	ns	-1.1	Ns
Favela	68.2	****	75.5	****	75.9	****	70.4	****	61.8	****
Vote for Bolsonaro	7.3	****	**13.2**	****	**27.5**	****	**33.6**	****	**45.2**	****
Nb. Days without measure	0.1	****	0.1	****	0.1	****	0.1	****	0.1	**
Informal worker	48.0	****	**80.7**	****	88.4	****	**109.0**	****	126.1	****
Poverty * Informal	-184.9	****	**-330.9**	****	-348.9	****	**-424.6**	****	-473.8	****
Tests (100 000h)	0.0	****	0.0	****	0.0	****	0.0	****	0.0	****
Nb. Days of COVID19	2.5	****	**4.4**	****	**12.4**	****	**21.4**	****	**36.8**	****
Nb. Observations	**4,775**		**5,269**		**5,269**		**5,269**		**5,258**	
R2	**0.27**		**0.30**		**0.27**		**0.25**		**0.23**	

Sources: Ministry of Health, IBGE, Facebook ; authors' calculations.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Notes: The data in bold correspond to the coefficients where we observe an acceleration from one month to the next.

Regarding the contamination rate, here too, the effect of skin color appears to be one of the most robust (**Table A3** in the Appendix). Being White not only reduces the number of confirmed cases, but the effect is becoming more and more important. While it was insignificant in June, a 10 ppts increase in the proportion of white population within the *municipio* reduced the contamination rate by 26.5 persons per 100,000 inhabitants in July and by 52.8 in August, an increase in the rate of "protection". No other socio-economic characteristic knows such a marked dynamic. We can suppose that white people have more resources of all kinds than the others to avoid contamination, especially in terms of containment strategy.

Poverty and preference for President Bolsonaro are two other factors whose negative effects have increased at certain periods. An increase of 10 ppt of the vote for Bolsonaro corresponded to 37.2 additional cases per 100,000 inhabitants in June against 165 in October. One can suggest that the declarations minimizing the pandemic and calling for a rapid return to business as usual has met more and more echoes on the relaxation of

social distancing instructions from its supporters (and probably beyond). The effect of most of the other characteristics of *municipios* tend to fade over time, but still very significant.

In conclusion, the analysis of the evolution of the pandemic over time shows that the impact of race, Bolsonaro's vote and to a lesser extent, poverty and informality are at the same time the most robust effects and in expansion. This result is confirmed by the panel regression which considers a time trend and a crossed effect of this trend and the four factors (see **Table A5** in the appendix).

4.3 Robustness Checks

In order to consolidate our results, we carried out a number of robustness tests, beyond the comparison of models over time presented above. Firstly, one of the main weak points of our analyses comes from the fact that a certain number of socio-economic variables are drawn from the 2010 population census (PC2010), the last available in Brazil, while the country has experienced notable changes over the past decade. As a preliminary, it is important to keep in mind that the time lag in the data is not a problem as far as the relative ranking of municipalities did not changes substancially over time. However, there are good reasons to think that most of the socio-demographic characteristics used in our models are structural features which only distort very slowly. To test this hypothesis, we compared their evolution between the different previous PCs.

Table 8 shows the correlation between all available variables in 1991, 2000 and 2010 Census. For most of them, the correlations are very high (between 0.8 and 1), both between 2000 and 2010, and between 1991 and 2000. For instance, the average income per capita correlation was 0.92 between the last two PCs (2010 and 2000), 0.91 between 2000 and 1991. Over twenty years (1991-2010), the income correlation is as high as 0.86. This shows that the inter-*municipios* rankings have changed very little over time for the main socio-economic characteristics.

Table 8: Socio-economic correlations over time (PC1991, 2000 and 2010) and PNAD-C

	Population Census			Population Census vs PNAD-C		
	2010-2000	2000-1991	2010-1991	2019-2010		2019-2010
Male rate	0,788	0,788	0,765	0,803	White	0,987
Tertiary education	0,884	0,916	0,843	0,970	Age	
Life expectancy	0,888	0,937	0,846	-	Own account	0,447
Poverty	0,884	0,916	0,843		Unemployed	0,787
Average income	0,919	0,913	0,859	0,970	Inactive	0,624
Promiscuity rate	0,928	0,908	0,842			
Access to water	0,775	0,396	0,560			
Active Population	0,998	-	-			
Youth in informal jobs	0,929	-	-			

Sources: Population Census 1991, 2000 and 2010, and PNAD-C 2019, IBGE; authors' calculations.

In this context, it is unlikely that the situation has changed drastically between 2010 and 2020. In order to (partially) assess this conclusion, we compared the results of the PC2010 with those provided by the PNAD-C 2019. As PNAD-C is not representative at the municipal level, we computed the correlations at the most granular level available in the PNAD-C, namely the 74 geographic areas corresponding to the partition into 3 types of territories (capital, metropolitan region and others) at the level of the 27 States. Again, the correlations are high. The conclusion of this exercise is that if the use of the data of the PC2010 induces some noise, it is likely to be limited and does not call into question our results.

Secondly, we tested numerous **alternative specifications** of our models (in log, weighted by *municipios* population and in panels). All confirmed the robustness of our results. Regarding the estimation of the linear panel model, it supposes that the effects of our main explanatory variables (constant over the studied period) do not change over time. A state fixed effect regression was also considered. In spite of some slight changes in the level of some coeficients, globally, we get the same significant effects for our explanatory variables (**Tables A4 and A5** in the appendix). Besides, we also substituted the variables of interest with other **alternative measures** whenever these were available: for example, by replacing the GDP per capita by the income per capita from PC2010 ; by substituting

different elements to capture the characteristics of the health system (presence of SUS hospitals, number of UTI beds in the *municipio*); by introducing the synthetic municipal human development index (IFDHM) developed by FIRJAN (2018) on the model instead of the UNDP Human Development Index, as well as its three sub-components instead of our variables education, health, and employment & income. Here too the results are confirmed.

Finally, in a certain number of (mainly developed) countries where the information is available, **a measure of excess mortality** is considered more reliable than the official data on deaths due to COVID-19 (see for example for an application in the case of France, Brandily et al., 2020). It should be emphasized that this indicator is not without problems (the observed excess mortality is not necessarily due to COVID-19; the definition of the baseline is arbitrary, etc.) and above all depends on the quality of the mortality data (identification of the cause deaths, compilation of data, etc.). In Brazil, these conditions are not met: the consolidated mortality data are not official until two years after being recorded (Marinho et al., 2020). Today, the latest official data available date from 2018. After a careful evaluation of the micro-data, our own assessment is that the excess mortality data is less reliable than the official data for deaths due to COVID-19. Some studies which have attempt to compare official data on COVID-19 deaths and the excess mortality for some cities in Brazil where the data are less problematic shows that the difference appears to be relatively limited compared to other countries. If the underestimation was estimated as potentially important in June (Veiga e Silva et al., 2020), the gap is decreasing over time (*The Economist*, 2020).

Nevertheless and in spite of these major gaps, we estimated the excess mortality using different methodological options (comparing the deaths in 2020 to the average of 2017 and 2018[20] or to the three previous years; for the 5 months since January or only for 3 months: March, April and May) based on open data from the Ministry of Health. With all the reservations of rigor on data quality, we re-estimated our model with this new measurement of the mortality rate. The results show a much lower explanatory power

[20] For these two years, 2017 and 2018, normally, the data are less subject to further corrections. On the contrary, the cleaning and verification processes for the 2019 data are not yet completely achieved.

(**Table A6** in the appendix). However, the main variables of interest remain significant and of the same sign as in our basic model. Life expectancy negatively impacts the death rate, while the density, the proportion of favela inhabitants, as well as water access difficulties and overcrowded housing tend to increase the mortality rate. The effect of race does not appear significant, which could be explained by the fact that it was not at work at the start of the epidemic in May with a still low number of deaths: less than 30,000 (and more than two thirds of the *municipios* without any death due to COVID-19).

Conclusion

The results found in the article are very clear. The econometric models proposed were estimated at five different times over the months of June to October 2020. The results were repeatedly showing the effect of the various variables tested on the contamination and mortality of COVID-19. As expected, the absolute values of the coefficients undergo modifications pointing to variables that increased and others that decreased their effect with the course of the pandemic, but the positive or negative association and the high levels of significance remained throughout the analyzed period. Several robustness tests were carried out to strengthen the results found. We highlight below the main results.

In terms of socioeconomic factors, the effect of skin color is the most robust. The study shows that, under equal conditions, the municipalities with more whites are the least affected. This result remains, regardless of the many control variables considered and, therefore, goes beyond the vulnerability factors that non-white populations suffer from already widely documented: education, poverty, informality, degraded housing, etc.

The level of poverty, measured by the rate of beneficiaries of emergency aid, is also a risk factor in the contamination index. The greater the poverty, the more the municipalities are affected by COVID-19. However, emergency aid has a mitigating effect in locations where there are relatively more informal workers, the latter being able to limit their commuting to work and thus better protect themselves. The health status of the population also weights on contamination. The municipalities with the lowest life expectancy and human development index are the ones that suffer most from the pandemic.

Among the socioeconomic factors, the municipalities where informal workers are more numerous are also the most affected, in addition to the amplifying effect of higher poverty rates. We can assume that the lack of social security and the need to move around in the exercise of their work contribute to this specificity of those who are informal.

Demographic density factors are also decisive. The most densely populated, the most urban municipalities and those with the largest share of the population living in slums pay a higher price. Difficulties in accessing water and sanitation infrastructure are also risk factors (especially in terms of mortality). We also highlight the influence of policy and

similar elements. Thus, in municipalities where containment measures were taken earlier, the pandemic was better controlled, being an indicator of the effectiveness of this type of policy. More original, the study showed that COVID-19 causes more damage in municipalities more favorable to President Bolsonaro. The president's ambiguous speech and attitudes may induce his supporters to adopt more risky behaviors (less respect for the instructions on confinement and wearing the mask) and to suffer the consequences.

It is necessary to remember that all the results highlighted above take into account control variables introduced in the models to avoid distorted results: number of tests performed (for proven cases) and number of days since the beginning of the pandemic, which also work in the expected direction; as well as health infrastructure (number of hospital and medical beds).

Finally, we want to highlight once again the importance of the municipal approach used in this article, which is the only way to incorporate the entire Brazilian population and all regions of the country in the analysis based on the data sources available in Brazil.

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APPENDIX

Table A1: Description of the variables

Variables	Description	Sources
Race (White)	% of white in the *municipios* [0,1]	Censo 2010
Sex (Male)	% of male in the *municipios* [0,1]	Censo 2010
Tertiary education	% of persons with tertiary education in the *municipios* [0,1]	Censo 2010
GDP/cap	Gross Domestic Product per capita (log)	IBGE, 2018
Poverty (AE)	% of beneficiaries of the *Auxilio Emergencial* [0,1]	Censo 2010
Age (log)	Age in average (log)	Censo 2010
Life Expectancy (log)	Life expectancy (log)	FIRJAN
Nb. Doctors (/100,000 h)	Rate: Number of doctors per 100,000 inhabitants	IBGE, Health2019
Nb. UTI beds (/100,000h)	Rate: Number of UTI beds per 100,000 inhabitants	IBGE, Health2019
Density (log)	Population size/area size (log)	IBGE, 2019
Area (Rural)	% of domicile in rural areas [0,1]	Censo 2010
Migration	% of migrants (born in another *municipios*) [0,1]	Censo 2010
Work Mobility	% of persons who work outside the *municipios* [0,1]	Censo 2010
Promiscuity	Number of persons per room	Censo 2010
No Water Access	% persons in domiciles with problem of water access[0,1]	Censo 2010
Favela	% of domiciles in *aglomerados subnormais (favela*) [0,1]	IBGE, 2019
Vote for Bolsonaro	% vote for Bolsonaro (1st round) 2018 presidential election [0,1]	TSF 2018
Nb. Days without measure	Nb of days without confinement measure since the 1st case	Facebook
Informal worker	% informal workers (Censo2010 adjusted with PNADC_2019) [0,1]	Censo 2010*
Tests (100,000h)	Rate: Nb of tests per 100,000 inhabitants (availab. at State level)	Min. Saude/Fiocruz
Nb. Days of COVID19	Nb of days since the 1st case of Covid_19 in the *municipios*	Brasil.IO

Note: all the variables are considered at the *municipios* level.

Table A2: Associated factors with COVID19 confirmed cases (for 100,000 inhabitants; OLS)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
White	-936.1****	-956.5****		-1195.0****	-393.8****	-288.2***	-242.5**	-524.4****	-527.5****
(%)	(0.000)	(0.000)		(0.000)	(0.000)	(0.009)	(0.026)	(0.000)	(0.000)
Sex (Male)		9797.1****		7946.6****	3848.3****	3836.7***	2241.0	849.7	1484.7
(%)		(0.000)		(0.000)	(0.001)	(0.007)	(0.119)	(0.555)	(0.306)
Tertiary education		1780.4**		-1789.9**	-857.3	-4027.5****	-3838.7****	-4586.7****	-3807.9****
(%)		(0.016)		(0.037)	(0.373)	(0.000)	(0.000)	(0.000)	(0.001)
GDP/head			215.3****	341.8****	269.7****	236.2****	269.4****	234.4****	246.3****
(log)			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Auxilio (Poverty)			3620.4****	953.1***	1407.8****	1407.4****	1290.9****	1800.3****	5667.1****
(%)			(0.000)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age					-3051.2****	-2904.7****	-688.6**	-531.3	-900.0***
(log)					(0.000)	(0.000)	(0.040)	(0.112)	(0.009)

Life expectancy	1584.8**	1508.1**	1412.7**	9.745	78.64
(log)	(0.013)	(0.021)	(0.032)	(0.988)	(0.907)
Nbr. Doctors	0.476**	0.501**	0.431**	0.399**	0.421**
(100 000 habitants)	(0.017)	(0.015)	(0.034)	(0.049)	(0.037)
Density		-15.19	-24.18	-18.00	-11.48
(log)		(0.314)	(0.111)	(0.234)	(0.454)
Area (Rural)		-410.5****	-510.4****	-391.6****	-522.2****
(%)		(0.000)	(0.000)	(0.000)	(0.000)
Migration		175.9	369.7***	81.22	52.67
(%)		(0.115)	(0.001)	(0.489)	(0.653)
Work mobility		-273.4*	-344.8**	-324.3**	-200.2
(%)		(0.086)	(0.029)	(0.039)	(0.238)
Promiscuity			1167.8****	1204.2****	1113.5****
(%)			(0.000)	(0.000)	(0.000)

Water access (No)							484.6***	524.4***	542.3****
(%)							(0.003)	(0.001)	(0.001)
Favela							1534.9****	1312.4****	1070.7***
(%)							(0.000)	(0.000)	(0.001)
Vote Bolsonaro								1231.7****	1203.9****
(%)								(0.000)	(0.000)
Nbr days without confinement								1.465**	1.304*
(log)								(0.035)	(0.060)
Informal worker									3128.9****
(%)									(0.000)
Poverty*Informal									-12288.4****
									(0.000)
Test	0.188****	0.194****	0.185****	0.204****	0.190****	0.197****	0.184****	0.189****	0.193****
(for 100 000 inhab.)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Nbr days pandemic	726.5****	797.4****	783.4****	832.9****	625.6****	636.4****	571.9****	481.8****	484.3****
(log)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-2443.7****	-7776.0****	-6006.8****	-10345.3****	-3368.5	-3072.6	-9115.1***	-2541.4	-3019.6
	(0.000)	(0.000)	(0.000)	(0.000)	(0.216)	(0.274)	(0.002)	(0.401)	(0.322)
N	5481	5471	5346	5331	5331	5262	5260	5259	5259
R^2	0.202	0.215	0.179	0.226	0.255	0.260	0.272	0.283	0.286
adj. R^2	0.202	0.214	0.178	0.225	0.254	0.258	0.270	0.280	0.283
AIC	91389.7	91146.3	89333.1	88783.9	88583.6	87422.9	87293.2	87207.0	87185.4

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.00$

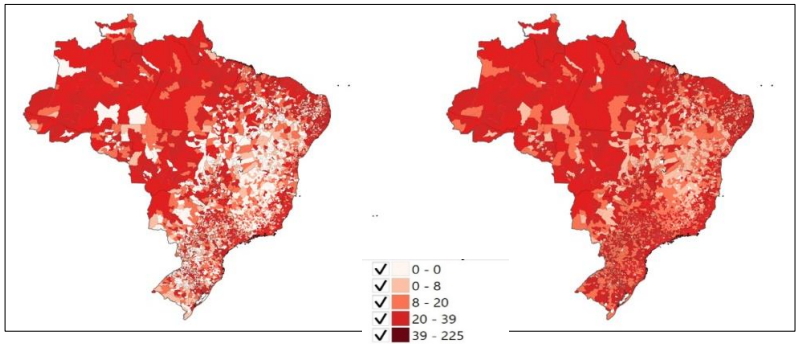
Figure A1: Simulations to illustrate the effect of four main explanatory factors

For each variable considered (% of white, % vote for Bolsonaro, % of poor, % of informal workers), the simulation suppose that the factor is reduced to 0% for all *mnicipios.*

BRANCO EFFECT

Mortality rate (per *municipios*, Aug. 11th)

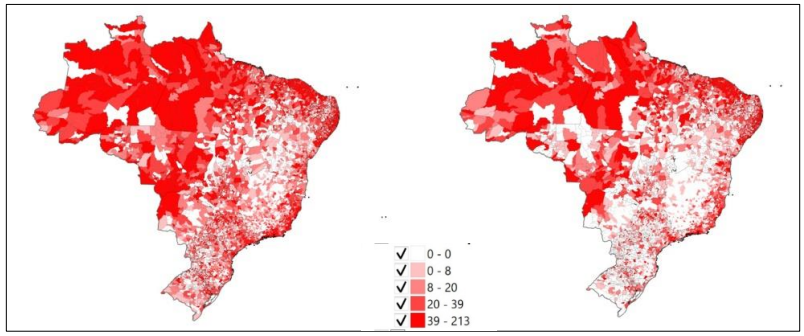
Simulation without any "Branco effect"



BOLSONARO EFFECT

Mortality rate (per *municipios*, Aug. 11th)

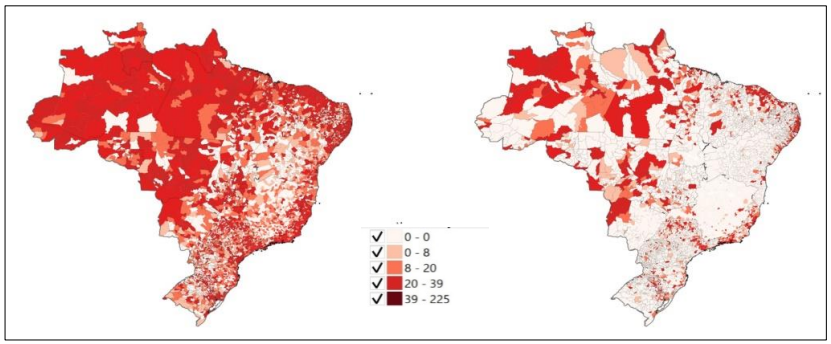
Simulation without any "Bolsonaro effect"



POVERTY EFFECT

Mortality rate (per *municipios*, Aug. 11th)

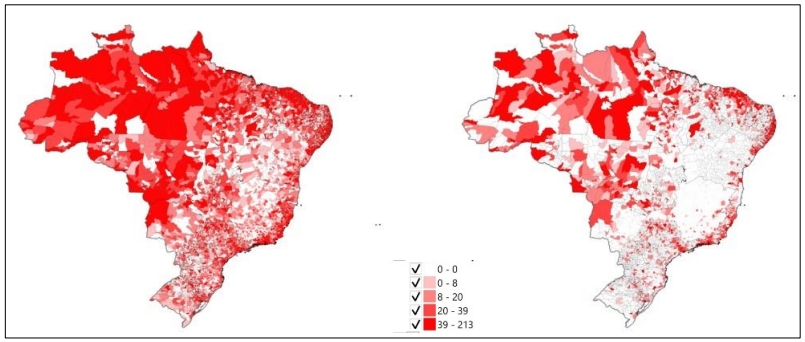
Simulation without any "poverty effect"



INFORMAL EFFECT

Mortality rate (per *municipios*, Aug. 11th)

Simulation without any "informal effect"



Source: Ministry of Health/Brasil.IO (https://data.brasil.io/dataset/covid19/_meta/list.html, accessed 11 August 2020); authors' calculations.

Table A4- Factors associated with mortality and infection rates: Results of the linear panel model (from June 21st to October 11th)

	Mortality rate (per 100.000)						**Confirmed Cases** (rate/100.000)					
	Linear model (Ref.) (August 11)		**Panel model**		**Panel model** (State fixed effect)		Linear model (Ref.) (August 11)		**Panel model**		**Panel model** (with State fixed effect)	
Race (White)	-18.3	****	-24.4	****	-21.8	****	-527.5	****	-498.1	****	-658.9	****
Sex (Male)	59.8	*	101.0	****	132.4	****	1484.7	ns	1 354.1	ns	4 296.0	****
Tertiary education	-44.5	*	-54.0	**	-41.1	**	-3807.9	****	-2 762.7	***	-1 973.0	**
GDP/cap (log)	6.3	****	6.6	****	5.2	****	246.3	****	264.3	****	287.2	****
Poverty (AE)	167.0	****	180.4	****	154.2	****	5667.1	****	6 066.7	****	4 811.5	****
Age (log)	28.8	****	35.2	****	47.0	****	-900.0	***	-879.5	***	811.4	***
Life Expectancy (log)	-38.9	**	-13.3	ns	-19.1	ns	78.6	ns	-473.4	ns	-1 258.7	**
Nb. Doctors (100 000 h)	0.0	Ns	0.0	ns	0.0	ns	0.4	**	0.5	***	0.5	***
Density (log)	2.8	****	3.6	****	2.9	****	-11.5	ns	-4.5	ns	1.3	ns
Area (Rural)	-12.6	****	-19.6	****	-11.1	****	-522.2	****	-613.9	****	-253.9	***
Migration	-1.5	Ns	-2.6	ns	-5.3	ns	52.7	ns	51.3	ns	261.8	**
Work Mobility	7.9	*	3.6	ns	15.9	****	-200.2	ns	-207.7	ns	458.4	***
Promiscuity	36.3	****	33.6	****	19.2	****	1113.5	****	1 064.2	****	484.7	***
No Water Access	3.5	Ns	8.6	**	-12.0	****	542.3	****	730.9	****	-529.8	****
Favela	75.9	****	64.8	****	51.5	****	1070.7	****	991.0	****	-648.2	***
Vote for Bolsonaro	27.5	****	30.6	****	27.5	****	1203.9	****	1 243.2	****	1 184.7	****
Nb. Days without measure	0.1	****	0.1	****	0.0	ns	1.3	*	2.9	****	-3.2	****
Informal worker	88.4	****	101.2	****	67.6	****	3128.9	****	3 067.3	****	1 480.0	***
Poverty * Informal	-348.9	****	-391.2	****	-284.6	****	-12288.4	****	-13 087.3	****	-7 277.4	***
Tests (100 000h)	0.0	****	0.0	****			0.2	****	0.2	****		****
Nb. Days of COVID19	12.4	****	3.0	****	15.5	****	484.3	****	192.4	****	839.8	****
Nb. Observations	5 269		25 841		25 841		5259		25 723		25 723	
R2	0.27		0.31		0.34		0.29		0.36		0.38	

Sources: Ministry of Health, IBGE, Facebook; authors' calculations.

* $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$. **** $p < 0.001$

Panel regression with time trend and crossed effects

$$Y_{it} = a_0 + b_0 t + \alpha_m^T X_i^m + h_m^T \, t * X_i^m + \beta_n^T E_i^n + \gamma_k S_{it}^k + \delta_l C_{it}^l + u_{it} \qquad (3)$$

Where *t* captures the time trend

X_i^m vector of individual socio-economic variables (of dimension m)

$t * X_i^m$ crossed effect of the variables and the time trend *t*

Table A5- Evolution of the effects of the four factors: Results of the panel model with time trend and crossed effects

Mortality rate	**α** (X)		**h** (t*X)		**June 21**	**July 17**	**Aug. 11**	**Sept. 3**	**Oct. 11**
Race (White)	4.45	ns	-0.14	****	-11.2	-14.6	-17.9	-21.2	-26.2
Poverty (AE)	-54.27	ns	0.50	****	3.8	16.4	28.5	40.6	59.3
Vote for Bolsonaro	-5.30	***	1.02	****	111.4	136.8	161.2	185.6	223.1
Informal worker	131.16	***	-0.26	****	100.7	94.1	87.7	81.4	71.6
Confirmed cases	**α** (X)		**h** (t*X)		**June 21**	**July 17**	**Aug. 11**	**Sept. 3**	**Oct. 11**
Race (White)	1714.1	***	-11.6	****	376.6	85.9	-193.2	-472.4	-902.7
Poverty (AE)	-1972.8	ns	19.2	****	232.9	712.4	1172.7	1633.0	2342.7
Vote for Bolsonaro	46.9	***	32.1	****	3740.3	4543.3	5314.1	6084.9	7273.2
Informal worker	4932.6	***	-14.6	****	3258.7	2894.8	2545.5	2196.1	1657.6

Sources: Ministry of Health, IBGE, Facebook; authors' calculations.

* $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$. **** $p < 0.001$

Table A6: Results using measures of excess mortality. Factors associated with mortality rate (per 100 000 inhabitants)

	Linear regression model using measures of excess mortality					
	Mars-May 2020 / mean 2017-2018		**Janv-May 2020** /mean 2017-2019		**April-May** /mean 2017-2019	
Race (White)	-0.48	ns	2.00	ns	6.42	ns
Sex (Male)	152.59	ns	55.94	ns	185.87	**
Tertiary education	40.62	ns	108.77	ns	-36.54	ns
GDP/cap (log)	6.58	***	7.20	***	5.43	***
Poverty (AE)	195.69	***	299.05	****	183.58	****
Age (log)	22.46	ns	36.34	ns	14.50	ns
Life Expectancy (log)	-1.61	ns	-40.76	ns	-26.48	ns
Nb. Doctors (100 000 h)	-0.03	**	-0.04	***	-0.03	***
Density (log)	5.55	****	5.23	****	5.38	****
Area (Rural)	3.72	ns	3.83	ns	-5.40	ns
Migration	13.51	*	18.64	**	8.17	ns
Work Mobility	-18.07	ns	-18.09	ns	-26.33	***
Promiscuity	45.51	****	43.54	***	42.49	****
No Water Access	34.02	***	32.55	**	28.80	****
Favela	80.34	****	78.06	***	87.36	****
Vote for Bolsonaro	17.01	*	21.69	*	12.91	*
Nb. Days without measure	0.05	ns	0.08	ns	0.05	ns
Informal worker	57.04	ns	91.48	*	68.77	**
Poverty * Informal	-434.44	**	-674.46	***	-436.79	***
Nb. Days of COVID19	0.65	ns	-0.70	ns	1.09	*
Nb. Observations	**5,269**		**5,269**		**5,269**	
R2	**0.03**		**0.04**		**0.07**	

Sources: Ministry of Health. IBGE. Facebook; authors' calculations.

* $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$. **** $p < 0.001$