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Municípios in the time of Covid-19 in Brazil: socioeconomic vulnerabilities, transmission mechanisms and public policies[1]

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Abstract

Brazil is among the countries hardest hit by Covid-19 in terms of both numbers of confirmed cases and deaths. This paper paints a picture of the pandemic's progression in Brazil with a view to informing thinking on response policies implemented or to be promoted. The study's purpose is twofold: to identify the Covid-19 infection and mortality risk factors by social category, and to determine potential transmission channels and the effects of the different measures taken. The analysis at the level of all 5,570 Brazilian municipalities draws on a matching of different statistical and administrative databases, involving processing tens of millions of observations. The econometric analysis conducted at five different dates returns three main results. First, structurally vulnerable populations are hardest hit – non-white, poor, in poor health, *favela* residents and informal workers – highlighting the impact of socioeconomic inequalities in the spread of the disease. Second, "density" (both in neighbourhoods and housing) and "mobility" are decisive. Third, we highlight some policy repercussions. The pandemic has been brought under control more in *municipios* where lockdown measures were taken sooner. The *Auxilio Emergencial* (emergency cash transfer) has had a mitigating effect in communities with relatively more informal workers, enabling them to restrict commuting and thereby better protect themselves. Finally, Covid-19 has hit hardest in *municipios* that are more pro-Bolsonaro. The president's ambiguous rhetoric and attitudes may have prompted his supporters to adopt more risky behaviour, suffer the consequences and infect others.

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

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

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[1] The paper is also published as a Discussion Paper by the Instituto de Economia of the Universidade Federal do Rio de Janeiro (IE/UFRJ) : Texto para Discussão No.32-2020 [https://www.ie.ufrj.br/publicacoes-j/textos-para-discussao.html].

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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, Politicas 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 oeuvre 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-clefs : Brésil, COVID-19, Municipalités, Inégalités socio-économiques, Informalité, Politiques publiques

Introduction

Brazil ranks second among the countries hardest hit by Covid-19 in terms of numbers of deaths and third in terms of numbers of confirmed cases. Our study presents details on the progression of the pandemic in Brazil to help understand the outcomes of response policies implemented or to be promoted. Although epidemiological studies are on the rise, studies of the socioeconomic factors of Covid-19 transmission remain thin on the ground. This situation is especially problematic in that although individuals' biological characteristics play a role, they are not the only factors in play. Their impacts are highly dependent on their interaction with individual and collective human behaviour. A better understanding of the pandemic's progression and effectiveness of response policies can only be gained by considering these two dimensions together. Such is the contribution that this paper intends to make. To our knowledge, it is the first study of its kind on Brazil.

The purpose of our study is twofold: to identify the Covid-19 infection and mortality risk factors by social category, and to determine the potential transmission channels and the effects of different measures. The analysis at the level of all the country's 5,570 municipalities (*municípios*) draws on a wide range of statistical and administrative databases.

This municipality approach, which rounds out the individual-level analyses, has a number of advantages, mainly that: i) it is the only approach to guarantee an exhaustive analysis of all corresponding geographical localities in the country; ii) the effects of the pandemic are manifested not only at the individual level, but also at the collective level; iii) socioeconomic surveys do not count deaths, while administrative health records are poor socioeconomic descriptors; and iv) most importantly, disease response policies are conducted at municipal level.

The first part of the paper conducts a brief review of the literature on the subject. The second presents an overview of the Brazilian context, discussing the epidemiological situation and the policies implemented. The third details the methodological approach, presents the data and provides initial descriptive statistics. The fourth discusses the results and the dynamics since the start of the pandemic. Finally, the conclusion focuses on learnings and outlook.

I- Socioeconomic factors and Covid-19: a brief review of the literature

The growing literature on Covid-19 is very recent. Many studies are still in their preliminary versions and have not yet been peer-reviewed for publication in academic journals (Brodeur et al. 2020). The literature is essentially epidemiological and, to a lesser extent, economic. We present an overview of selected available socioeconomic analyses on Brazil and a number of papers from the international literature which share our methodological approach. Among the studies on Brazil, we first review the results of the analyses based on individual data before looking into the specific contributions of analyses conducted at local level (municipality and state).

A first set of studies investigates the socioeconomic characteristics of people infected by Covid-19. Hallal et al. (2020) use individual data from a vast testing programme of 55,000 randomly selected participants in 133 cities nationwide. Their serological results suggest, among other things, a case underreporting figure of some 70%. The socioeconomic data collected show that the virus infects different population categories. In terms of ethnicity, indigenous people (*Índios*), followed by blacks (*Pretos*) and browns (*Pardos*), are found to have much higher seroprevalence rates than whites (6.3, 3.6, 3.4 and 1.4 respectively). Women appeared to be less infected by the disease when first tested in May. However, their prevalence rate on the second test in June was higher than for the men. In terms of age, the highest rate was found at between 30 and 59 years old. Living conditions indicators highlight the frail health of the poor, with prevalence increasing with the number of inhabitants per household and decreasing with household wealth.

Baqui et al. (2020) set out to identify the individual risk factors associated with Covid-19 mortality. They use the national flu database,[2] which provides a certain number of socioeconomic characteristics on each patient admitted to hospital: age, sex, region, skin colour typology and comorbidities. Despite there being 19,940 patients in the database who had tested positive as at 4 May 2020, the non-response rate was so high that the analysis ultimately covered a sample of just 6,882 patients. In addition to the classic risk factors of age and comorbidity, the Cox model estimation produces findings on risk by skin colour and region. Other things being equal, *Pretos* and *Pardos* have a 45% and 32% higher risk of dying than *Brancos*.

Batista et al. (2020) analyse the socioeconomic dimensions of Covid-19 deaths at national level. They identify a sub-sample of 29,933 individuals who had recovered or died from Covid-19 from a sample of 43,906 confirmed cases in the Ministry of Health's "Síndrome Respiratória Aguda Grave" (SRAG) database as at 18 May 2020. Using simple cross tables, the study shows that the case-fatality rate increases with age. It is also higher among indigenous people, *Pretos* and *Pardos*, as well as among people with a low level of education. The case-fatality rate is higher in the poorest municipalities (as per the 2010 IDHM ranking).

Another set of studies takes a different angle, focusing on vulnerability and risk factors using data at the individual level. Nassif-Pires et al. (2020) calculate the risks of infection and death based on the three dimensions of vulnerability: the "social" dimension, associated with working and housing conditions, access to health services and medical risks.[3] An analysis of vulnerability indices constructed for different population categories finds that the risks appear to be higher among indigenous people (*Índios*), *Pretos* and *Pardos*. In general, women are less vulnerable, although *Preto*, *Pardo* and indigenous women present higher values than the population average as a whole. In terms of income, the risk decreases almost continuously along the richer deciles and the racial inequalities observed are reproduced for all levels. A lower level of education is associated with a higher risk. In terms of medical characteristics, comorbid conditions are found more among the less educated population, which adds force to the higher risks found for vulnerable populations.

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[2] "Sistema de informação de vigilância epidemiológica da gripe" (SIVEP-Gripe) published by the Brazilian Ministry of Health (http://plataforma.saude.gov.br/coronavirus/dados-abertos/).

[3] The medical risks considered and covered by the medical literature are: being over 60 years of age and diagnosed with diabetes, hypertension, asthma, lung disease, coronary disease or chronic kidney disease. The authors used individual data from the "Pesquisa Nacional de Saúde" (National Health Survey, IBGE 2013).

In a similar work, Nunes et al. (2020) analyse health, work and housing vulnerabilities in tandem. The authors use the same sources as the previous study, but with additional variables and a different methodology (Probit model estimates). Economic vulnerability is captured by labour market informality. Housing vulnerability covers access to water and sanitation, household density (ratio of number of people per room), type of construction and the existence of household waste collection. Analysis by level of education, age and federal state shows that while the elderly are more vulnerable in terms of health, young people are not spared. Almost half of the population under 60 years old present at least one health risk factor and are the most vulnerable economically. Indeed, these characteristics often overlap. The analysis by federal state turns up significant regional disparities. Greater housing vulnerability in the country's poorest regions compounds economic vulnerability and the fragile health systems in these same regions.

In the same vein, Tavares and Betti (2020) construct two specific indices: the "Covid-19 prevention index" and the "Covid-19 recovery index". They use the Alkire-Foster (AF) methodology for multidimensional poverty measures and a fuzzy-set approach. Results suggest that at least 15% and 13% of the Brazilian population have strong limitations on their preventing and recovering from Covid-19 due to social conditions and the healthcare system. Both vulnerability indices reveal huge inequalities among states and among ethnic groups: indigenous, brown and black people are more at risk of being infected and facing more recovery difficulties. The geography of prevention and recovery vulnerabilities is similar to the geographies of the Covid-19 mortality rate and monetary poverty, confirming i) the relevance of the proposed Covid-19 vulnerability indices, and ii) that both monetary and non-monetary measures are relevant in mitigating the effects of the pandemic.

Regarding analyses undertaken at the local (geographical) level, two papers cover the entire national territory[4] and analyse the political factors that are also addressed in our paper. First, Argentieri Mariani et al. (2020) investigate the effect of President Bolsonaro's sceptical attitude to the Covid-19 pandemic. The authors conduct a difference-in-difference analysis of both the pro-Bolsonaro *municipios* (those where the president won more than 50% of the total votes in the first round of the 2018 election) and the other *municipios*, before and after the demonstrations[5] of 15 March 2020. Pro-government demonstrations were held in 250 of the 1,050 *municipios* that registered at least one case of Covid-19 prior to 15 April 2020. Several indicators of the impact of Covid-19 are tested (including excess hospitalisations and excess mortality). This natural experiment shows that the *municipios* where demonstrations were held registered more hospitalisations and deaths than the others. The authors believe that this effect is due both to people gathering at the demonstrations and laxer attitudes to social distancing in keeping with the president's rhetoric and position.

Secondly, Ajzenman et al. (2020) also set out to assess the importance of the president's rhetoric. They estimate a fixed-effects panel model for the Brazilian municipalities. The results show that, in pro-Bolsonaro municipalities (also identified by the 2018 election results), people's mobility increases consistently in the week following the president's actions and words

[4] For papers on the socioeconomic factors of Covid-19 infections and deaths in specific cities and states, see Miranda et al. (2020), De Negri et al. (2020) and Silveira et al. (2020).

[5] These pro-government demonstrations were held by the president's supporters following growing criticism and dissatisfaction with his rhetoric and attitude.

to make light of the impacts of the pandemic and discourage compliance with social distancing. This effect is stronger in municipalities with a significant local media presence, a high number of Twitter accounts (a social network used extensively by the president) and a high proportion of evangelists.

At the international level, McLaren (2020) analyses racial disparities in Covid-19 mortality at U.S. county level. This study is closer to ours in terms of method and research questions. The author takes a sample of 3,140 counties, representing 322 million U.S. residents, and compares mortality data (as of 19 May 2020) with census data to show that the proportion of deaths is closely correlated with the proportion of African Americans (and First Nations) in the county, and that this correlation is robust to the introduction of control variables such as education, income, type of job (occupation, commuting and teleworking compatibility) and health insurance. Brown and Ravallion (2020) conduct a more in-depth analysis of the impact of poverty and inequality on infection rates in the U.S. at county level. They also find a strong race effect whose predominance is illustrated by the fact that income inequality and poverty effects vanish when they control for the share of Black Americans.

Lastly, Brandily et al. (2020) undertake an ambitious analysis at municipality level in France. They show that the epidemic disproportionately affects the poorest municipalities. Poor housing conditions (especially overcrowding) and occupational exposure appear to be the most likely transmission mechanisms. This work has many advantages over other studies. First, the variable of interest is not the number of deaths recorded, with their unanimously recognised biases, but excess mortality over the number of deaths in the previous year. Second, they draw on a combination of different data sources on the 30,000 French municipalities. Third, they take a quasi-experimental (triple difference) approach to estimate the causal impact of the pandemic.

To conclude this brief literature review, almost all existing studies on Brazil find that vulnerability – estimated or observed (by infection or death rate) – is higher for more fragile populations from several points of view. Studies are unanimous that non-whites are harder hit by Covid-19, as are older people. Evidence of the most fragile groups' greater vulnerability to Covid-19 is also highlighted in three other dimensions: economic conditions (income and work), housing – with the two being linked – and level of education. The only aspect on which the studies are not unanimous concerns the differences between men and women. Although women might be expected to stay at home more than men – for economic and cultural reasons[6] – effectively reducing the infection rate, results differ between studies.

This study seeks to improve on the above mentioned analysis of Brazil with a wide array of variables to cover the multiple dimensions of the factors affecting the progression of the pandemic, such as socioeconomic, demographic, cultural (political and religious) and economic policy-related factors. Conducted at municipality level and at different dates to monitor the impact of each factor over time, this analysis provides insights to complement existing studies.

[6] Nassif-Pires et al. (2020b) reproduce data from a survey in the U.S. which shows that women feel more concerned about the disease, report having changed their routine more often, and have lost their job or reduced their working hours more than men. The situation does not appear to be any different in Brazil in that several articles show that the number of hours spent on household tasks is higher for women and that more women than men have found themselves unemployed since the start of the pandemic because of their greater presence in the service sector – especially as domestic workers – and the informal sector.

II- The Brazilian context

II.1- The epidemiological situation

Brazil is among the countries hardest hit by the Covid-19 pandemic. In October 2020, official sources ranked it second worldwide, behind the United States, with over 150,000 deaths, and third, behind the United States and India, with over 5,000,000 confirmed cases (**Table 1)**. These figures should be viewed with caution due to underestimation (of the number of cases) and poor data quality in most of the world's countries. Yet Brazil's particularly low testing rate would appear to bear out this ranking.[7] When ranked as a ratio of the country's population, however, Brazil is not among the hardest hit by the pandemic even though it remains high on the board with 710 deaths and 24,000 confirmed cases per million inhabitants.

Table 1: Top ten countries hit by Covid-19 worldwide (14 October 2020)

	Deaths	**Mortality rate** (per million/inhab.)	**Confirmed Cases**	**Infection Rate** (per 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**

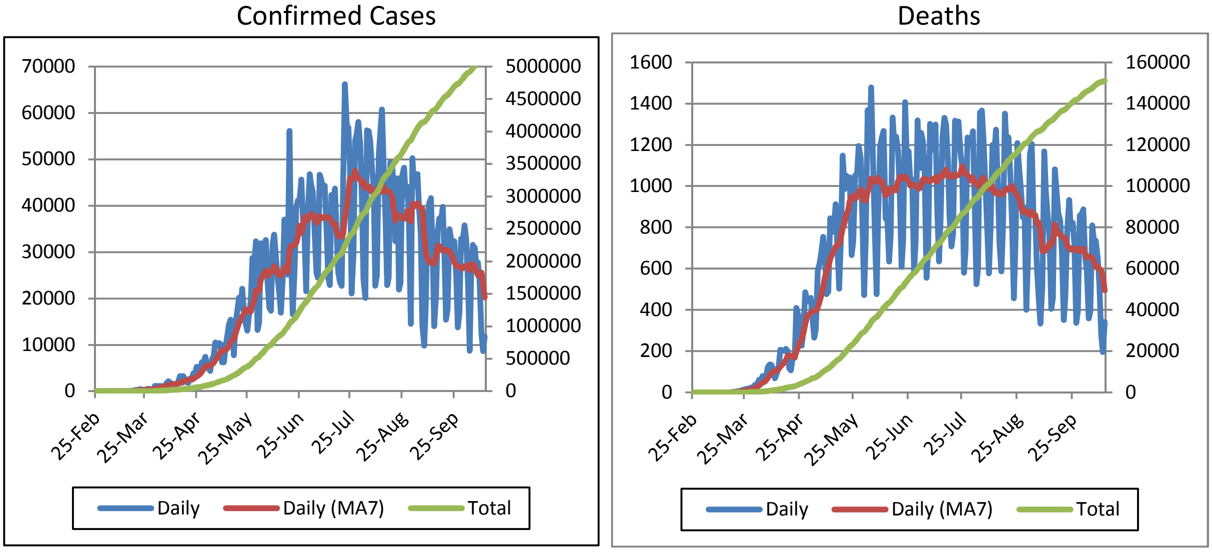
Source: "Covid-19 Coronavirus Pandemic," Worldometer, last updated 14 October 2020, https://www.worldometers.info/coronavirus

Figure 1 shows the trend in the daily and cumulative numbers of confirmed cases and deaths. Both figures show numbers still running high, although on the downturn, through to October. Following a sharp rise in the first three months (March to May), the number of deaths plateaued. From late May to mid-August, the death toll stabilised at a high level of around 1,000 per day before gradually declining through the end of October, albeit still at over 400 deaths per day on average. Confirmed cases reached a first plateau of some 25,000 cases per day in early June. This number rose to around 37,000 in the first half of July before peaking at 46,000 on average in late July and then falling from that date on. By early October, the moving average stood at some 25,000 cases per day.[8]

[7] See Section 3 for a discussion on sanitary and economic policies adopted.

[8] A new rise in the number of cases in November signalled the second wave of the pandemic for Brazil.

Figure 1: Confirmed cases and deaths 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 (last seven days). **Total** on the right-hand 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.

II.2-Policy responses

In terms of policy responses to the coronavirus pandemic, two types of measures have been taken worldwide: i) public health measures – called non-pharmaceutical interventions (NPIs) – to reduce contact rates in the population and thereby the transmission of the virus; and ii) economic policies to cushion the health crisis's adverse impacts on households and businesses.

Since the announcement of the Covid-19 pandemic by the World Health Organization on 11 March 2020, "social distancing" has been the main NPI recommended to control the spread of the new coronavirus. National governments worldwide have defined actions to implement this such as the suspension of non-essential businesses, self-isolating at home, teleworking and movement restrictions in cities.

In Brazil, President Bolsonaro's main response has been to dismiss the virus as a danger, calling it a "little flu" (*gripezinha*) and discouraging social distancing and lockdown measures on the grounds of their negative economic repercussions for the country. Much like President Trump's handling of the pandemic crisis, the Brazilian government's actions bear the marks of a particular context that features a combination of a lack of a comprehensive NPI and domestic political crisis within the government. Such disarray at central public administration level sows confusion and negatively impacts the population's compliance with mitigation measures. Given the President of the Republic's denialist stance and the lack of united, coordinated action by the Ministry of Health at national level, subnational government (state governors and city mayors) has taken the lead in tackling the pandemic crisis (Fonseca et al. 2020).

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

June 21 *July 17* *August 11* *September 03* *October 11*

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

June 21 *July 17* *August 11* *September 03* *October 11*

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

In March 2020, all Brazilian states closed their schools and non-essential businesses and suspended social events. In April, the states started to develop plans to ease their social distancing measures. These plans had been adopted by 21 states by the end of July 2020. Moraes, Silva and Toscano (2020) discuss the broad diversity of these plans in terms of format, technical criteria and transparency, as well as the number of municipalities taking up their state's plan. These plans' performance and success have been hindered by the absence of an adequate testing policy.

These lockdown measures unleashed an economic crisis unprecedented in recent history and revealed huge socioeconomic inequalities in capacities to cope with the uncertainties of the pandemic. The hardest hit have been those who find it harder to work from home and earn the income to pay the bills.

Emergency social policies to guarantee basic income for the most vulnerable and policies to support workers and businesses are key to prevent the pandemic crisis from deepening socioeconomic inequalities and poverty. The Brazilian government consequently introduced a raft of measures to tackle the negative effects of the pandemic. The federal government adopted two sets of emergency economic policy measures (Silva 2020; Waltenberg, da Silva and da Silva 2020): i) tax measures to guarantee family incomes, support businesses and provide financial assistance to states and municipalities; and ii) liquidity support and regulatory capital measures to ensure the stability of the financial system and expand the credit supply.

Focusing on the first set of measures, which directly impact the population, the Brazilian government launched an emergency plan to guarantee a minimum income for the most vulnerable people. The Emergency Aid for People in Vulnerable Situations (Auxílio Emergencial a Pessoas em Situação de Vulnerabilidade (AE)), the most popular measure during the pandemic, was launched in April 2020. Following a strong civil society campaign and intense pressure from Congress, the federal government introduced an Emergency Basic Income of R$600 per month, instead of the R$200 initially proposed by the government.[9] The cash transfer was basically intended for informal workers in vulnerable situations. Following the three-month experiment, the government opted to extend it through to August 2020. In September, the benefit was then extended through to December 2020 at the reduced sum of R$300. This AE cash transfer programme represented a substantial amount in terms of public expenditure, far above equivalent programmes in Latin American countries (World Bank 2020).

In July 2020, the Brazilian government launched a further programme to guarantee income in the shape of the Emergency Benefit to Maintain Employment and Income (Benefício Emergencial para Preservação do Emprego e da Renda - BEM) for low-income formal employees. This programme introduced a proportional reduction in working hours with wages paid at 25%, 50% or 70% of the full wage for three months or temporary suspension of the employment contract and payment of emergency benefit for two months, later extended through to December 2020. The government tops up the employees' income based on the amount of unemployment benefit to which they would be entitled.

[9] US$1 = R$5.5. This value corresponds to 60% of the national minimum wage (R$1,045).

Despite design and implementation problems with the Emergency Aid and Emergency Benefit Programmes, they have been quite successful at protecting income and, to a lesser extent, jobs. As at 31 August 2020, 67.2 million people were covered by the Emergency Aid Programme with 84% receiving R$600 in benefit and 16% receiving R$1,200.[10] As at 31 July 2020, 12.4 million Emergency Benefit Programme work agreements had been signed, with employees receiving an average monthly benefit of R$863.

The Brazilian labour market was already seriously struggling prior to the pandemic and, despite the relative success of the two programmes, the labour market has slumped throughout 2020. The early months of Covid-19 saw a huge outflow of people from the labour force, mainly from the informal sector due to movement restrictions. The increase in the unemployment rate was consequently relatively small. The relaxation of social distancing measures subsequently brought a slight economic recovery and the return of part of the labour force. However, perhaps the most striking labour market figure in the first six months of the pandemic was the 12 million job losses, slashing the number of employed from 94 to 82 million.

Central government also introduced Financial Aid for States, Municipalities and the Federal District, another important measure as the subnational governments were hard hit by the decrease in tax revenues, the increase in spending on hospitals and welfare, and the increase in Ministry of Health spending. However, the abovementioned Emergency Aid for People in Vulnerable Situations and Emergency Benefit to Maintain Employment and Income were the main measures taken by the federal government to mitigate the impacts of Covid-19. Through to September 2020, they accounted for 64% of the 2020 expenditure prevision to fight the pandemic.

The IMF (2020) estimates Brazil's revenue, expenditure and financial measures at 10% of the country's GDP. Brazil´s spending is lower than the developed countries – particularly Germany, Italy, Japan and the UK – but exceeds most of the other developing and emerging economies.

The government's emergency income guarantee plan in response to the pandemic crisis appears to have reached the most vulnerable in large numbers, narrowing inequalities in per capita household income (Carvalho 2020). It is worth mentioning that the effort made to identify and register Emergency Aid beneficiaries has laid a building block for the future to facilitate access to large-scale welfare programmes in Brazil.

II3- Policy and actual population mobility

Despite President Bolsonaro's ambiguous, if not outright hostile attitude, and the Ministry of Health's hesitancy, both economic and public health policy has tended to focus on restricting population movements. However, actual mobility depends not only on policy, but also on the authorities' capacity to enforce its measures and the extent of the populations' support for these measures. Data from *Google Mobility* and *Facebook Movement Range Maps*[11] reveal a sharp and massive drop in mobility in Brazil from 13 to 25 March 2020 (Figure 3).

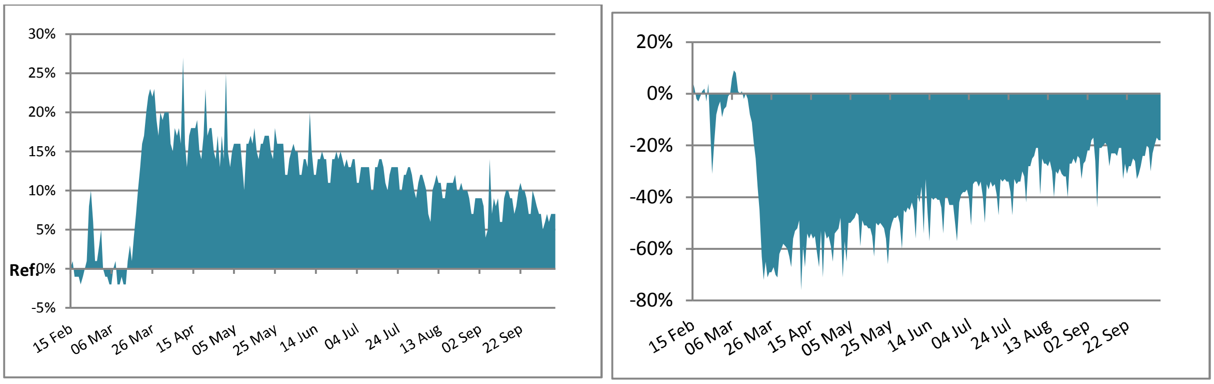
[10] Lone-parent families headed by women received R$1,200. See https://aplicacoes.mds.gov.br/sagi/ data

[11] https://dataforgood.fb.com/tools/movement-range-maps/

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

Google Data

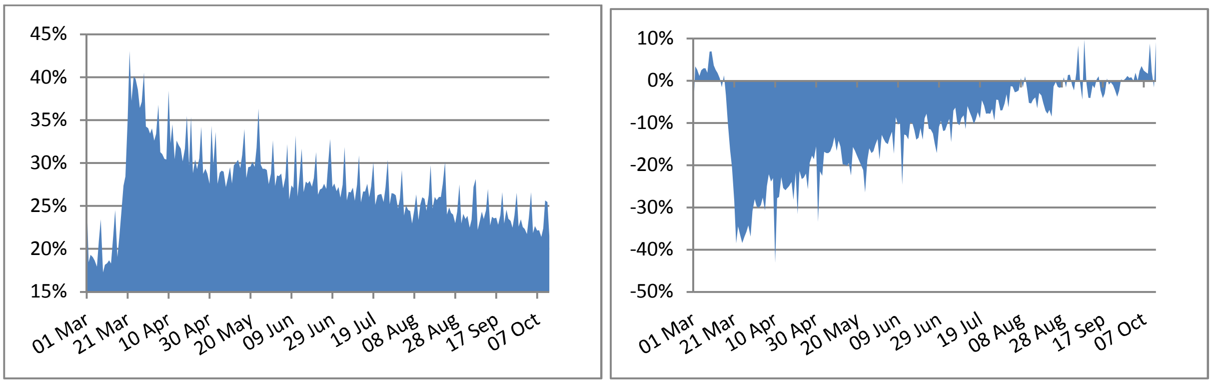
Staying at home (%) Stores frequentation (%)



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

Rate of people staying in a unique place (%) Mobility gap (%)

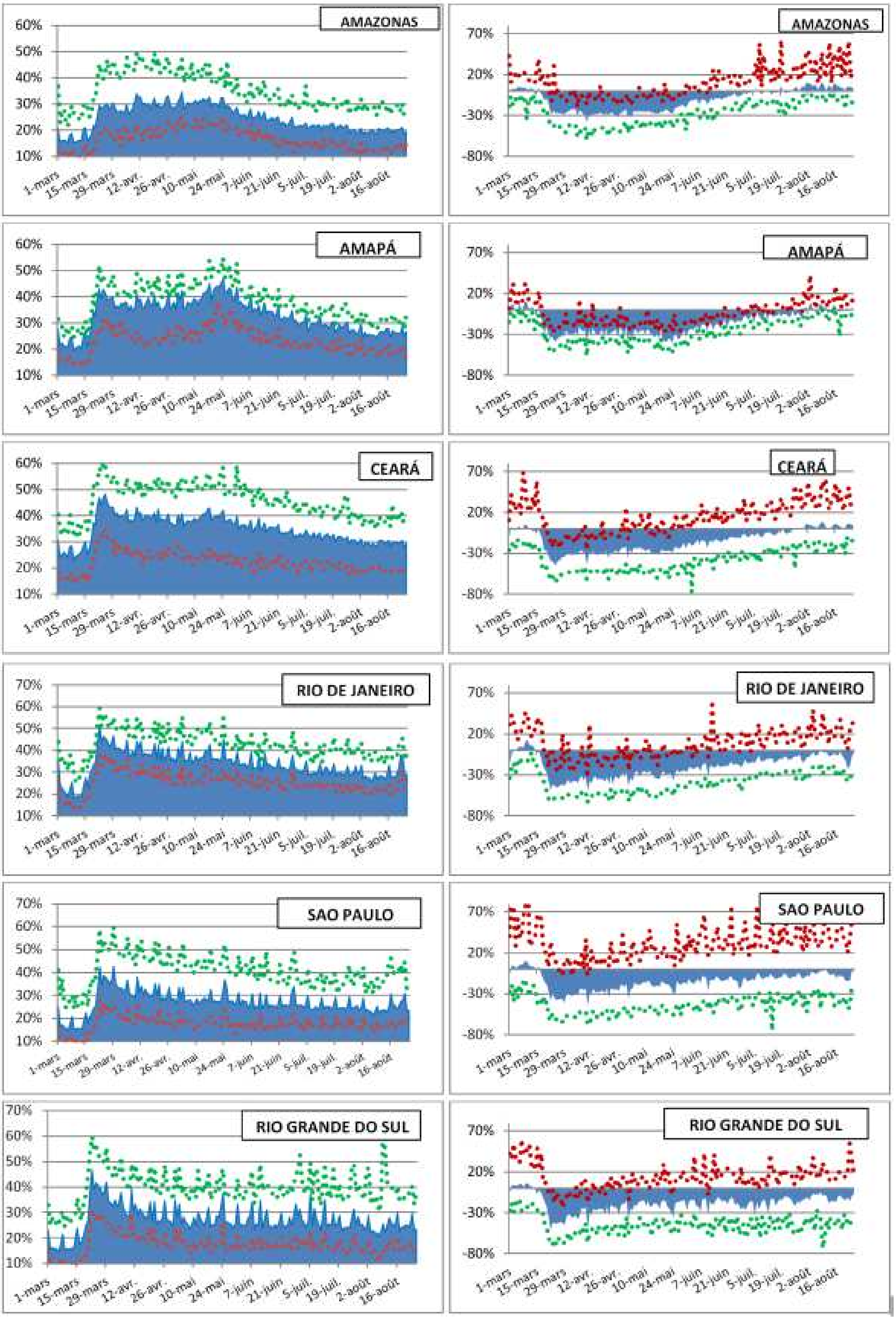


Source: *Movement range maps*, Facebook; authors' calculations.
Note: The left panel corresponds to the percentage of those who did not move during the day; The right panel, corresponds to the deviation of those who left home compared to a period of reference (February).

Hereafter, lockdown gradually eased under the dual effect of the relaxation measures and less compliance by the population, albeit without returning to pre-pandemic conditions. Facebook data show that at the height of lockdown (end of March), only 40% of the population stayed at home all day. This rate fell to 25% in early October, barely 5 points higher than in the pre-lockdown period (beginning of March).

However, this national trend obscures differences observed at municipal level, which Facebook data reveal to be highly diverse. **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.

III- Methodology, data and descriptive statistics

The unit of analysis is the *municipio,* of which there are 5,570 in Brazil. First, it is the smallest administrative entity for which comprehensive data can be gathered on Covid-19, health indicators and the population's socioeconomic characteristics. Second, not only does it cover the entire country, but it can also capture the effects of both collective behaviour (or neighbourhood behaviour) and individual behaviour. Lastly, many policies are designed and implemented at municipal level, as shown in section 2. Therefore, the *municipio* approach has a number of advantages.

However, it is not without its limitations and results are to be interpreted with due caution. First, the analysis by municipalities cannot be mechanically transposed in terms of individual risks. But at least, a significant effect at municipal level guarantees that it is also significant in terms of individual odds. It can be assumed that individual and *municipio* approaches generally converge in terms of signs. If not, inverse mechanisms would need to be explained.[12] The empirical results of the individual approach help substantiate our interpretations. Second, the econometric models tested here can be used to estimate the links between the confirmed case and mortality rates and the different factors, corrected for structural effects. The study consequently does not claim to identify the causal impact of these factors. However, methodologically speaking, clear causal identification has to focus on one particular factor. It is not suited to jointly identifying multifactor links and painting the broad picture we intend to give in this paper. All things considered, the two methods are complementary, when ideally combined, without one being superior to the other.

III.1 Empirical strategy, data and variables

The fatality rate and rate of confirmed cases are modelled to identify the characteristics of the *municípios* hardest hit by the pandemic. Given the fact that the data on confirmed cases and deaths are highly non-normally distributed and substantially overdispersed count data, the parameters are estimated by a negative binomial (NB) model[13] using maximum likelihood.

$$Y_i = \exp(a_0 + \alpha_m X_i^m + \beta_n E_i^n + \gamma_k S_i^k + \delta_l C_i^l + \delta_0 T_i + u_i) \qquad (1)$$

Y_i represents the dependent variables: either the death rate or the rate of confirmed cases in the municipality i (cumulative counts).[14] X_i^m is the vector of the individual socioeconomic variables (dimension m), E_i^n the vector of the environmental variables at municipal level, S_i^k the vector of the measures or policies, C_i^l the vector of the control variables, and T_i is the number of days since the first case (exposure time).

[12] For example, if the municipalities with higher male ratios are harder hit, it does not necessarily mean that males are hardest hit. Women in municipalities where male ratios are high could be most at risk of infection. However, this would imply finding a particular mechanism to support this view.
[13] A naïve model with a linear model (OLS) was also considered. Overall, we obtained quite similar results with the same order of magnitude.
[14] The data used are based on bulletins issued by the Ministry of Health compiled by Brasil.io, an independent organisation recognised for the quality of the data they make accessible to all types of users. See the robustness checks for more detailed information and discussion on the quality of the data.

Estimation covered different dates. At the same time, we used panel models to better reflect the progression of the epidemic over time. Two types of specification were tested:

$$Y_{it} = \exp(a_0 + \alpha_m X_i^m + \beta_n E_i^n + \gamma_k S_{it}^k + \delta_l C_{it}^l + \delta_0 T_{it} + u_{it}) \qquad (2)$$

$$Y_{it} = \exp(a_0 + \alpha_m X_i^m + h_m\, T_{it} * X_i^m + \beta_n E_i^n + \gamma_k S_{it}^k + \delta_l C_{it}^l + \delta_0 T_{it} + u_{it}) \quad (3)$$

The introduction of the cross effect with the time trend (equation 3) takes into consideration that the effect of one factor (whose level is constant) might change over time.

Three major groups of explanatory factors were considered:

(1) The first group consists of individual variables regarding sociodemographic characteristics (sex, age, race, education, state of health and migration status) and socioeconomic characteristics (poverty and situation on the labour market). In addition to these classic variables, we also included an indicator on movement outside the *municípios* for professional reasons, a potential factor in the spread of infection.

(2) The second group comprises variables on the *municípios*: level of development (GDP per capita), density, location (urban/rural), type of settlement (favela) and housing (overcrowding and access to sanitation), and health infrastructure.

(3) The third group includes variables reflecting certain policies implemented (directly or indirectly): start date of lockdown measures; percentage of President Bolsonaro supporters, assuming these are the people the most reluctant to respect the measures; and percentage of *Auxilio Emergencial* (AE) beneficiaries among the population.

We added the number of days since the first case (or exposure time) to these three groups of independent variables, since the pandemic did not start at the same time in the different *municípios*. The number of tests performed was taken as a control variable to limit the effects of the potential bias or underestimation of the fatality or Covid-19 confirmed case data.[15]

The data used come from various sources: census, survey data, administrative records and big data (see Table A1 in Appendix). The Covid-19 data comes from the Ministry of Health's multi-institutional programme to count confirmed cases and deaths. Although the confirmed cases are clearly underestimated (due to a faulty testing policy), they are much less so for deaths. Unlike many other countries, official Brazilian Covid-19 data are much more reliable than excess mortality estimates. However, we use excess mortality as a robustness check. Independent variables imply the processing of tens of millions of observations. Again, Brazil offers a particularly data access-friendly environment. In addition to a recognised public statistics system, the active open government policy gave us access to valuable information on different

[15] This could be debatable because if the variation in the test rate is not random, but depends on the infection rate, then the test rate should not be used for the correction. The solution used here is to control by the test rate available at state level, assuming that the test rate in each state varies between municipalities according to the infection rate.

transparency portals. We also used Facebook *Movement Range Maps* to compute our lockdown indicator at municipality level.[16]

III.2 Descriptive statistics

As at 11 August 2020, at the peak of the first wave of the pandemic, the average infection and fatality rates per *municipios* stood at 1,081 and 23 per 100,000 inhabitants respectively. They were hugely dispersed ranging from 6 to 15,730 for the infection rate and from 0 to 213 for the fatality rate. At this date, 1,766 *municipios* had recorded no deaths (**Table A2** in the appendix). Simple correlations provide a first glimpse of the links between infection and death rates and the variables included in the analysis (**Table 2**). As expected, the infection rate depends on the test rate and the number of epidemic days in absolute terms and without lockdown (0.31, 0.32 and 0.13). It also depends on the rate of overcrowding in dwellings (0.36). Counterintuitively, it is negatively related to age (-0.36): the more young people there are in the *municipio*, the more the disease spreads. Of all the sociodemographic variables, the strongest correlation is observed for race (-0.22 for the proportion of whites in the *municipio*). The infection rate is also a function of poverty (0.17).[17]

Table 2: Main variable correlations

Variable	Confirmed cases	Deaths	Variable	Confirmed cases	Deaths
Covid-19 (11 August)			**Socioeconomic & labour market**		
Fatality Rate	+0.512***	-	GDP per capita	+0.026	+0.022
Test (state level)	+0.308***	+0.172***	Gini	+0.223***	+0.169***
Nb. days since 1st case	+0.316***	+0.399***	Auxilio Emergencial (AE)	+0.168***	+0.152***
			Informal Worker	-0.053***	-0.080***
Sociodemographic			Commuting	-0.020	+0.116***
Sex (male)	+0.030	-0.114***	**Health**		
Age (average)	-0.348***	-0.247***	Access to water (no)	+0.251***	+0.159***
Education (<=primary)	+0.050***	-0.061***	Life expectancy	-0.162***	-0.113***
Education (higher)	-0.073***	+0.005	State hospital	+0.149***	+0.150*
Race (white)	-0.221***	-0.186***	Nb. doctors/100k	+0.026	+0.080***
Migration	+0.024	+0.028	Nb. ICU beds/100k	+0.049***	+0.114***
Socio-political			**Density/Housing**		
Vote Bolsonaro (1st round)	-0.058***	-0.027	Density	+0.037***	+0.205***
Evangelist	+0.122***	+0.177***	Rural	-0.039***	-0.138***
Nb. days without			Favela	+0.171***	+0.303***
Lockdown	+0.129***	+0.214***	Overcrowding (house)	+0.377***	+0.262***

Sources: Ministry of Health, IBGE, Facebook Movement Range data; Authors' calculations.
* p < 0.10, ** p < 0.05, *** p < 0.01, **** p < 0.001

[16] We used Facebook data to identify the lockdown start date for each municipality. We did not use the extent of compliance with lockdown measures as an explanatory factor for two reasons: first, because of possible reverse causality (compliance is greater in *municipios* with higher death rates); and second, because it would have absorbed the effect of some characteristics, which is precisely what we set out to measure (e.g. informal workers might be harder hit because they cannot comply with the restrictions).
[17] The poverty rate is proxied by the number of beneficiaries of the *Auxilio Emergencial*, the emergency aid reserved for poor families.

With respect to the mortality rate, the correlations are generally of the same sign and the same order of magnitude as for the infection rate. Among the most striking results, mortality is a decreasing function of age (-0.25). Mortality increases with density (0.21), as it does with work-related travel outside the *municipio*. Lastly, 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.

The socioeconomic 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), *municipio* development (0.59), life expectancy (0.66) and age (0.70). On the political front, the share of whites increases with the vote for Bolsonaro (0.69). These correlations between socioeconomic variables are important to mention. Indeed, the simple (unconditional) correlations between Covid-19 indicators and these variables might ultimately merely reflect structural effects.

IV- Results and discussion

IV1- The basic model

Estimation covered different dates (from June to October), but we will first discuss the result for 11 August, date of the peak of the first wave in Brazil. A stepwise procedure, which adds socioeconomic characteristics one by one until the model is complete, can be used to assess the robustness of the effects (Table A3 and A4 in the appendix). The results identify the main social groups at risk.

Sociodemographic indicators: First, as expected, age matters. *Municipios* where the population is older on average are harder hit in terms of deaths. However, *municipios* with older people appear to have relatively fewer confirmed cases. Since this was initially neither the case in June nor in July (coefficients not significant),[18] this change is compatible with the dynamics of the pandemic which is increasingly affecting young people. The gender effect is not really robust (coefficients not always significant), but tends to confirm that men are more at risk. This result is in line with Griffith et al. (2020), who put forward a combination of epidemiological factors and social behaviour, with men tending to engage in more risky behaviour in general. Higher education has a negative effect on mortality and especially on confirmed cases. This result is especially robust in that this effect is *a priori* underestimated, as the more educated go to be tested more often.[19] It could be suggested that it is due to better access to information and more careful behaviour.

Health status and healthcare infrastructures: logically speaking, longer average life expectancy, which can be interpreted as an overall health indicator (combined with the prevalence of comorbidity factors), reduces the death and infection rate in the municipality. Healthcare infrastructures as captured by the available indicators (presence of a state hospital, ratio of medical staff and number of beds) have no influence on either the presence of the disease or the mortality rate. Some potential positive results (better patient care) might be offset

[18] See Table 4 below and Table A5 in the Appendix.
[19] The PNAD-Covid results show that the test rate increased in August with level of education from 4% for those with no education or incomplete primary to 18% for those who completed higher education (authors' calculations).

by other negative effects (high level of infection among healthcare professionals; McLaren 2020)

Race: *Municipios* with a higher percentage of whites are more likely to be spared, both in terms of confirmed cases and deaths.[20] This is the most significant and robust effect of all our regressions. The effect is especially striking in that it adds to the other aggravating factors included in the models from which non-white populations also suffer: a lower level of education, higher poverty rate, larger informal economy and poorer housing conditions (residence in *favelas* with more overcrowding, less access to public sanitation services), etc.[21]

Socio-political indicator: Other things being equal, the *municipios* where Bolsonaro obtained his best scores during the first round of the 2018 presidential election (the hard core of the president's supporters) are also harder hit, in a reversal of the initial negative correlation (Table 2). This sign change comes from the specific profile of the president's supporters: better off, more educated and more often white (Gomes de Souza 2019; Rennó 2020). It can be explained by the president's tactics to make light of the pandemic in his statements (*uma gripezinha*) and attitudes (participation in demonstrations and dismissing masks as protection). His supporters are consequently encouraged to ignore or comply less with measures designed to counter the disease. Our results are in line with other studies based on quasi-experimental approaches (Argentieri Mariani et al. 2020; Ajzenman et al. 2020) conducted in the early stages of the pandemic. Similarly, several papers show that Republican supporters in the U.S. respect social distancing measures less often (Allcott et al. 2020; Painter and Qiu 2020).

Economic development and poverty: The most developed *municipios* are those with the highest rates of infection and mortality. Indeed, the epidemic started in the big cities (with the first cases recorded in São Paulo) and spread the fastest in these cities due to the intensity of social interactions (exchanges, population movements, diversity of economic and social activities). However, the poorer the *municipio*, the harder it is hit (mortality and confirmed cases[22]). This result is consistent with a growing number of studies in other countries (Brandily et al. 2020). As the poverty effect holds when controlling for GDP per capita, our results suggest that the greater the inequalities, the higher the rate of infection and deaths.

Labour market: The models show that the *municipios* with the highest share of informal jobs have the highest infection and death rates. This effect is not a disguised income effect, since the model controls for poverty. One of the possible explanations is that informal jobs are more exposed (roving vendors, street pitches, interactions with clients and fewer possibilities for teleworking[23]). Another explanation is that informal workers without access to welfare are forced to continue working and are therefore at a greater risk of infection (to themselves and others). However, the coefficient of the cross effect of informality and the *Auxilio Emergencial* is negative. It seems that informal workers have been able to reduce their structurally higher movements with the help of the emergency aid reserved for the poorest families.

[20] The PNAD-Covid (IBGE, 2020) results place the test rate slightly higher among whites (9% in August) than among black and coloured people (8%).
[21] Similar results are found in a growing number of studies (see McLaren, 2020, for example, for the U.S.).
[22] The effect is a conservative estimate for confirmed cases as the test rate increases with household income (from 7% for those earning less than half the minimum wage per capita to 22% for those earning more than four times the minimum wage; PNAD-Covid, August 2020).
[23] See PNAD-Covid, August IBGE (2020).

Density and housing conditions: As expected, population density in the *municipio* is positively linked to the spread of the virus. Likewise, the coefficient for overcrowded housing (overcrowding) is an aggravating factor. This result is also found for the death rate in France (Brandily et al. 2020). Conversely, living in rural areas lowers the rate of deaths and confirmed cases. On another note, the proportion of people living in *favelas* increases the impact of Covid-19. This effect transcends socioeconomic profile (poverty, health status, etc.), housing density and overcrowded dwellings, since these factors have already been taken into account. Neither is the "*favela* effect" a disguised impact of a lack of access to water and sanitation. We isolated the negative effect of no water access or sanitation on the infection rate (but not on mortality). We can therefore assume that the lack of access to basic services (excluding water services) penalises *municipios* with a significant presence of *favelas*. The remarkable response of inhabitants and associations working in the *favelas* (Fiocruz 2020) has not been enough to cancel out the adverse effects of years of government underinvestment in these neighbourhoods.

Mobility Indicators: As expected, mobility indicators are positively correlated with the spread of the virus. The more mobile a *municipio*'s inhabitants, the higher the rate of confirmed cases. This effect can be observed right from the start of the pandemic: the longer the time lag between the first confirmed case and population lockdown measures, the higher the infection rates. It is also observed in *municipios* with migrants or where workers have to travel outside the *municipios* to their workplace.

IV2- Simulations

To get an idea of the orders of magnitude of the effects, we conducted two types of simulations on our four main variables of interest (white or "*branco*", poverty, informality and "Bolsonaro") at the mean and by way of illustration, comparing two large well-known *municipios* that are different in terms of each variable considered. As **Table 3** suggests, the size of the effects is far from negligible. For the *branco* effect, an increase of 10 ppts in the proportion of whites in a *municipio* reduces the mortality rate per 100,000 inhabitants by 1.6, corresponding to a 7% decrease in the average death rate per *municipio* (23). The corresponding decrease in the number of Covid-19 cases also stands at 7% of the average infection rate (1,081/100,000 inhabitants).

Taking now the two capital cities of Salvador (Bahia State) and Florianopolis (Santa Catarina), the proportion of whites in these cities differs immensely (19% and 85% respectively). If Salvador had the same proportion of whites as Florianopolis, its mortality rate would have been 27 points lower per 100,000 inhabitants. Therefore, according to this simulation, 764 lives would have been saved of the 2,003 actually observed in Salvador (i.e. a decrease of -38%) if non-whites had not suffered from disadvantages due to specific forms of discrimination.[24]

The effects are even greater for the poverty impact: on average, + 77% more deaths for an increase of 10 ppts in the poverty rate. The equivalent figure for the number of cases is + 42%. 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. 21% instead of 13%, it would have recorded 264 more deaths (+18 points for the mortality rate per 100,000 inhabitants). The increase over the 453 registered

[24] Apart from the ones linked to characteristics already considered in the model.

deaths in Porto Alegre would have been 58%. The growth in the number of confirmed cases comes to 32%. Meanwhile, the "Bolsonaro" effect leads first to 14% more deaths on average for a 10 ppt increase and second to 50% more deaths if Salvador, just 28% of which voted for the president in 2018, had voted the same way as Rio de Janeiro (58%).

Table 3: Size of the main effects (race, poverty, informality and "Bolsonaro")
(Two types of simulations: for a 10 ppt increase in each variable at the mean; comparing two *municipios* and applying the characteristics of the second to the first; 11 August 2020, NB model)

	Distri-bution of the variable	Simu-lation (+ppt)	Deaths			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 (Brazil)	47%	+10	23	-1.6	**-7%**	1,081	-72	**-7%**
Salvador (BA)	19%	+66	70	-27	**-38%**	2,178	-792	**-36%**
vs. Florianopolis (SC)	85%							
Poverty	*Poverty*							
Mean (Brazil)	22%	+10	23	18	**+77%**	1,081	451	**+42%**
Porto Alegre (RGS)	13%	+8	31	18	**+58%**	670	215	**+32%**
vs. Fortaleza (Ceara)	21%							
Informality	*Informality*							
Mean (Brazil)	31%	+10	23	8	**+33%**	1,081	280	**+26%**
Campinas (SP)	19%	+15	64	34	**+53%**	1,644	680	**+41%**
vs. Belém (Pará)	34%							
Informality*_Auxilio E._	*Auxilio*							
Mean (Brazil)	22%	+10	23	-5	**-22%**	1,081	-189	**-17%**
Campinas (SP)	14%	+9	64	-8	**-13%**	1,644	-171	**-10%**
vs. Belém (Pará)	23%							
Bolsonaro	*Bolsonaro*							
Mean (Brazil)	39%	+10	23	3	**+14%**	1,081	123	**+11%**
Salvador (BA)	28%	+30	70	35	**+50%**	2,178	832	**+38%**
vs. Rio de Janeiro (RJ))	58%							

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

Finally, informality in the labour market raises the number of deaths by 33% on average (for 10 ppts more informal jobs) and by 53% when comparing Campinas (São Paulo) with Belém (Pará). The informality*_Auxilio_ cross effect, which shows that the adverse effect of informality is partially offset by the *Auxilio Emergencial*, is also significant. For the same pair of cities, 102 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 25% of the 410 additional deaths caused by the 15 ppts of informality rate that separate Belém from Campinas (34% vs. 19%), or 13% of the total number of deaths recorded in this city.

IV3- Dynamics over time

Taking our study further, we estimated the full model at five different dates: on 21 June when the milestone of one million confirmed cases was crossed, on 17 July when the two million mark was reached, and so on until 11 October and five million cases. The corresponding figures for the number of deaths are 50,000, 75,000, 100,000, 125,000 and 150,000.[25] These estimates enable us to both test the robustness of the results and track the progression of the pandemic over time. On the first point, while some coefficients vary from one period to the next, the vast majority of them maintain their sign and level of significance. The models are therefore very robust, with the different factors always in the same direction throughout the pandemic (**Table 4** and **Table A5** in the Appendix).

Table 4: Evolution of factors associated with the mortality rate over time (100,000 inhabitants; NB)

	Death (date)									
	50,000 (21 June)		**75,000** (17 July)		**100,000** (11 August)		**125,000** (3 September)		**150,000** (11 October)	
Race (White)	-0.57	**	-0.75	****	-0.73	****	-0.66	****	-0.75	****
Sex (Male)	6.66	**	5.85	**	2.89	ns	4.21	**	3.01	*
Higher education	-0.97	ns	-3.45	*	-2.47	ns	-1.21	ns	-0.74	ns
GDP/cap (log)	0.28	****	0.25	****	0.23	****	0.23	****	0.21	****
Poverty (Auxilio Emerg. (AE))	8.65	****	8.81	****	5.73	****	6.13	****	5.86	****
Age (log)	4.39	****	3.19	****	1.54	***	1.40	***	1.88	****
Life Expectancy (log)	-5.38	****	-2.46	**	-2.58	**	-1.77	**	-1.64	**
Nb. Doctors (100,000 inhab.)	0.00	ns	0.00	ns	0.00	ns	0.00	*	0.00	ns
Density (log)	0.09	***	0.10	****	0.09	****	0.09	****	0.07	****
Area (Rural)	-0.61	**	-0.79	****	-0.53	****	-0.60	****	-0.69	****
Migration	0.49	*	0.57	**	0.27	ns	0.18	ns	0.21	ns
Commuting	1.20	***	0.51	ns	0.42	ns	0.40	*	0.35	*
Overcrowding	2.71	****	2.22	****	1.36	****	1.07	****	1.07	****
No Water Access	0.80	**	0.33	ns	0.35	ns	0.25	ns	0.09	ns
Favela	2.52	****	1.81	***	1.40	**	0.93	**	0.64	ns
Vote for Bolsonaro	0.74	**	0.53	*	1.34	****	1.24	****	1.25	****
Nb. days without measure	0.01	****	0.00	ns	0.00	ns	0.00	ns	0.00	ns
Informal worker	4.93	****	4.77	****	2.83	***	2.90	****	2.67	****
Informal *Auxilio Emer. (AE)	-20.37	****	-19.92	****	-11.24	***	-11.53	***	-9.99	***
Tests (100,000 inhab.)	0.00	***	0.00	***	0.00	****	0.00	****	0.00	****
Nb. days of Covid-19	0.71	****	1.11	****	0.93	****	1.03	****	1.24	****
Lnalpha_cons	1.40	****	1.10	****	0.77	****	0.50	****	0.20	****
Nb. Observations	**4,775**		**5,269**		**5,269**		**5,269**		**5,258**	

Sources: Ministry of Health, IBGE, Facebook; authors' calculations.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$
Note: Negative Binomial (NB) model.

Turning to the relative magnitude of the risk factors between June and October, the panel regression on the interaction effect with time enables us to assess how the coefficients change over time (see **Tables A6 & A7** in the appendix). The effects of three of our four main variables of interest (branco, poverty, informality) tend to diminish over time from the start of the pandemic in the municipality. The Bolsonaro effect appears to be an exception since the coefficient tends to increase over time.

IV4- Robustness Checks

We conducted a number of robustness tests to consolidate our results over and above the comparison of models over time presented above. One weak point in our analyses is due to the fact that a certain number of socioeconomic variables are drawn from the 2010 population census (PC2010), the latest available in Brazil, while the country has seen some striking changes

[25] 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).

in the past decade. First, bear in mind that the time lag in the data is not a problem in that the relative ranking of municipalities has not changed substantially over time. However, there is good reason to think that most of the sociodemographic characteristics used in our models are structural features, which change only very slowly. To test this hypothesis, we compared how they had changed between previous PCs.

Table A8 shows the correlation between all available variables in the 1991, 2000 and 2010 census. Most of 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 stood at 0.92 between the last two PCs (2010 and 2000) and at 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 in terms of the main socioeconomic characteristics.

In the light of this, it is unlikely that the situation would have changed drastically between 2010 and 2020. In order to (partially) check this conclusion, we compared the results of the PC2010 with those of the PNAD-C 2019. As PNAD-C is not representative at 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 three types of territories (capital, metropolitan region and others) at the level of the 27 States. Again, the correlations are high. We obtained the same result when we considered CAGED data on the percentage of formal workers. Therefore, although using the PC2010 data introduces some noise, it is likely to be limited and does not challenge our results.

Secondly, we tested numerous **alternative specifications** for our models (in log, weighted by *municipio* population and in panels).[26] All confirmed the robustness of our results. Different specifications were adopted for the estimation of the panel model. The first assumes that the effects of our main explanatory variables (constant over the period studied) do not change over time. Yet the results of the repeated cross-section approach appear to return changes for some coefficients. A second option takes into account a potential time trend. Lastly, a state fixed effect regression was also considered to account for any unobservable factors at state level that may impact on the spread of the virus. Given the fact that many variables are constant over time, the coefficient for the factors not interacted with time becomes hard to interpret. However, for our main variables of interest, despite some slight changes in the level of the coefficients, overall, we obtained the same significant effects for our explanatory variables (**Tables A6 and A7** in the appendix). In addition, we substituted the variables with other **alternative measures** whenever these were available: for example, replacing GDP per capita with income per capita from PC2010; substituting different elements to capture the health system's characteristics (presence of state hospitals and number of ICU beds in the *municipio*); introducing the composite municipal human development index (IFDHM) developed by FIRJAN (2018) into the model, instead of the UNDP Human Development Index, along with its three sub-components instead of our education, health, and employment & income variables. Here too, the results were borne out.

[26] Our study does not address the spatial spread of the pandemic which deserves specific analyses. However we also tested for spatial autocorrelations which happen to be very low and are not likely to question our results.

Lastly, in a certain number of (mainly developed) countries where the information is available, **a measure of excess mortality** is considered more reliable than official data on deaths due to Covid-19 (see Brandily et al. 2020, for example, for an application in the case of France). Note that this indicator is not without its issues (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 cause of death, compilation of data, etc.). In Brazil, these conditions are not met: consolidated mortality data are not official until two years after they have been recorded (Marinho et al. 2020). The latest available official data today date back to 2018. After careful consideration of the micro-data, our own verdict is that the excess mortality data is less reliable than the official data on deaths due to Covid-19. Some studies comparing official data on Covid-19 deaths with excess mortality data for certain cities in Brazil (where the latter are less problematic) find relatively small differences compared with other countries. Although underestimation cannot be denied (França et al. 2020; Souza et al. 2020) and was estimated as potentially large in June (Veiga e Silva et al. 2020), the gap is decreasing over time (*The Economist* 2020).

Nevertheless and despite these large gaps, we estimated excess mortality using different methodological options (comparing deaths in 2020 with the average for 2017 and 2018[27] and for the previous three years, for the 5 months since January and for just the three months of March, April and May) based on the only available data (open data from the Ministry of Health). With all the reservations of rigour with respect to data quality, we re-estimated our model with this new measurement of the mortality rate. The results reveal much less explanatory power (**Table A9** in the appendix). However, the main variables of interest remain significant and with the same sign as in our basic model.

Conclusion

Three major conclusions can be drawn from this analysis. First, on the methodological front, we show the extent to which the approach at municipal level can provide relevant and consistent results. It is the only way to include the entire Brazilian population and all the country's regions in the analysis and, at the same time, make use of a wide range of available data sources. For example, we show the extent to which the expected "agglomeration effects" impact on infection and mortality rates. The most densely populated, urban municipalities with overcrowded houses pay a higher price.

On the analytical front, the second main message supported by this study is that the Covid-19 pandemic has aggravated already huge socioeconomic inequalities in Brazil. Estimations made at different dates and using different specifications show that the risk of infection and death is higher for already disadvantaged groups. Such is the case for the poor, less educated, those with lowest life expectancy, informal workers, those living in poor housing, those with difficulties accessing water and *favela* inhabitants. Although rich municipalities have been harder hit, it is the poor in these locations who are more exposed. The gap between advantaged and disadvantaged individuals has been exacerbated by the pandemic. In addition, the study shows that, given equal conditions, municipalities with more whites have been the least hard hit. This

[27] For these two years, 2017 and 2018 the data are normally less subject to further corrections. However, the cleaning and verification processes for the 2019 data are not yet finished.

result holds irrespective of the many control variables considered and therefore transcends the abovementioned vulnerability factors applying to non-white populations. It can be assumed that this result is due to other prevailing forms of discrimination.[28]

The third message concerns the importance of policy responses: policy matters. Our results support the view that emergency aid has played a positive role. The *Auxilio Emergencial* has had a mitigating effect in locations where there are relatively more informal workers, enabling them to restrict commuting to work and thereby better protect themselves. We also highlight the influence of some specific measures. For example, the pandemic was brought more under control in municipalities where lockdown measures were taken sooner. Last but not least, the study shows that Covid-19 has caused more damage in more pro-Bolsonaro municipalities. The president's ambiguous rhetoric and attitudes may well have prompted his supporters to adopt more risky behaviour (less compliance with lockdown measures and the obligation to wear a mask in public spaces). Taking the interpretation further, this type of behaviour is detrimental not only at the individual level of the president's supporters, but more importantly it has wider repercussions at the collective level of the *municipio*. When the spread of the virus grows, paradoxically, the most vulnerable – for example, the poor – who were less inclined to vote for Bolsonaro in 2018 are the hardest hit.

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APPENDIX

Table A1: Description of the variables

Variables	Description	Sources
Race (White)	% of whites in the *municipios* [0,1]	Censo 2010
Sex (Male)	% of males in the *municipios* [0,1]	Censo 2010
Higher education	% of persons with higher 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]	Caixa, 2020
Age (log)	Age on average (log)	Censo 2010
Life Expectancy (log)	Life expectancy (log)	FIRJAN, 2018
Nb. Doctors (/100,000 h)	Rate: Number of doctors per 100,000 inhabitants	IBGE, Health2019
Nb. ICU beds (/100,000h)	Rate: Number of ICU beds per 100,000 inhabitants	IBGE, Health2019
Density (log)	Population size/area size (log)	IBGE, 2019
Area (Rural)	% of residences in rural areas [0,1]	Censo 2010
Migration	% of migrants (born in another *municipios*) [0,1]	Censo 2010
Commuting	% of persons who work outside the *municipios* [0,1]	Censo 2010
Overcrowding	Number of persons per room	Censo 2010
No Water Access	% persons in housing with water access problems [0,1]	Censo 2010
Favela	% of residences 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 measures	Nb. of days without lockdown measures since the 1st case	Facebook
Informal worker	% informal workers (Censo2010 adjusted by PNADC_2019) [0,1]	Censo 2010*
Tests (100,000h)	Rate: Nb. of tests per 100,000 inhabitants (available at State level)	Min. Saude/Fiocruz
Nb. Days of Covid-19	Nb. of days since the 1st case of Covid_19 in the *municipios*	Brasil.IO

Note: All variables are considered at *municipio* level.

Table A2: Descriptive Statistics

%	Average	Standard Deviation	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
Nb. days (since 1st case)	87	30	24	164	Min Saude/IO
Sociodemographic					
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 (higher)	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
Socioeconomic and labour market					
GDP per capita	21,991	20,946	3,285	344,847	IBGE 2018
Poverty *(Auxilio Emerg.)*	21.7%	6.8%	4.0%	80.4%	INSS-BPC
Informal worker	10.9%	3.7%	2.2%	31.4%	CENSO 2010
Commuting	5.3%	4.7%	0.0%	32.5%	CENSO 2010
Socio-political					
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
Nb. persons/room	0.7	0.16	0.42	2.09	CENSO 2010
Health System					
State hospital	47.2%	49.9%	0.0%	100.0%	MUNIC 2017
Health surveillance agency	98.4%	12.6%	0.0%	100.0%	MUNIC 2017
Nb. Doctors/100k	82%k	83.6%k	0%k	277%k	IBGE-health2019
Nb. ICU beds/100k	2.25%k	9.2%k	0%k	228%k	IBGE-health2019
Mobility/lockdown					
Nb. Days without lockdown/(since 1st case)	-29.3	23.5	-127	93	Facebook

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

Table A3: Factors associated with Covid-19 mortality (per 100,000 inhabitants; Negative binomial (NB) model)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
White	-0.681****	-0.702****		-0.788****	-0.533***	-0.494***	-0.437**	-0.745****	-0.728****
(%)	(0.000)	(0.000)		(0.000)	(0.002)	(0.005)	(0.014)	(0.000)	(0.000)
Sex (Male)		1.779		-0.141	-0.961	5.341**	3.329	1.948	2.886
(%)		(0.256)		(0.929)	(0.566)	(0.016)	(0.140)	(0.382)	(0.202)
Higher education		0.792		-0.795	0.152	-2.379	-2.450	-3.177*	-2.466
(%)		(0.466)		(0.508)	(0.914)	(0.147)	(0.139)	(0.052)	(0.136)
GDP/capita			0.177****	0.255****	0.245****	0.226****	0.269****	0.219****	0.227****
(log)			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Auxilio (Poverty)			3.206****	1.522***	1.531***	1.810****	1.630***	2.166****	5.734****
			(0.000)	(0.002)	(0.003)	(0.000)	(0.002)	(0.000)	(0.000)
Age					-0.755**	-0.718**	1.596***	1.843****	1.540***
(log)					(0.022)	(0.030)	(0.002)	(0.000)	(0.004)
Life expectancy					-0.511	-0.763	-1.028	-2.619***	-2.583**
(log)					(0.585)	(0.425)	(0.288)	(0.009)	(0.011)
Nb. Doctors					-0.0000124	-0.0000338	-0.000166	-0.000254	-0.000231
(100,000 habitants)					(0.972)	(0.926)	(0.648)	(0.477)	(0.518)
Density						0.0729***	0.0692***	0.0771****	0.0851****
(log)						(0.001)	(0.003)	(0.001)	(0.000)
Area (Rural)						-0.409***	-0.473***	-0.394***	-0.529****
(%)						(0.004)	(0.001)	(0.008)	(0.001)
Migration						0.325*	0.588***	0.280	0.273
(%)						(0.065)	(0.001)	(0.141)	(0.152)
Commuting						0.395	0.308	0.316	0.417
(%)						(0.108)	(0.208)	(0.194)	(0.116)

Overcrowding							1.298****	1.405****	1.364****
(%)							(0.000)	(0.000)	(0.000)
Water access (No)							0.343	0.366	0.345
(%)							(0.179)	(0.151)	(0.177)
Favela							1.956****	1.634***	1.398**
(%)							(0.000)	(0.003)	(0.010)
Vote Bolsonaro								1.379****	1.341****
(%)								(0.000)	(0.000)
Nb. days no measures								0.00157	0.00137
(log)								(0.146)	(0.204)
Informal worker									2.832***
(%)									(0.002)
Informal*AE Auxilio									-11.24***
									(0.007)
Test	0.00006****	0.00007****	0.00006****	0.00007****	0.00006****	0.00007****	0.00006****	0.00007****	0.00007****
(per 100,000 inhab.)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Nb. days pandemic	1.357****	1.368****	1.317****	1.273****	1.222****	1.105****	1.018****	0.927****	0.929****
(log)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-2.961****	-3.935****	-5.490****	-5.277****	0.141	-1.695	-7.126	0.0728	-0.509
	(0.000)	(0.000)	(0.000)	(0.000)	(0.972)	(0.687)	(0.110)	(0.987)	(0.914)
Lnalpha									
_cons	0.851****	0.850****	0.806****	0.797****	0.796****	0.798****	0.786****	0.777****	0.775****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N	5497	5487	5356	5341	5341	5272	5270	5269	5269

Sources: Ministry of Health, IBGE, Facebook; authors' calculations.
p-values in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table A4: Factors associated with Covid-19 confirmed cases (per 100,000 inhabitants; Negative binomial model)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
White	-0.705****	-0.673****		-0.944****	-0.435****	-0.421****	-0.405****	-0.687****	-0.685****
(%)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sex (Male)		8.406****		5.478****	3.183****	3.419***	2.679**	1.689	2.097*
(%)		(0.000)		(0.000)	(0.000)	(0.003)	(0.023)	(0.147)	(0.073)
Higher education		0.896		-2.473****	-1.476**	-3.800****	-3.835****	-4.358****	-3.841****
(%)		(0.126)		(0.000)	(0.050)	(0.000)	(0.000)	(0.000)	(0.000)
GDP/capita			0.168****	0.285****	0.266****	0.217****	0.239****	0.207****	0.218****
(log)			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Auxilio (Poverty)			2.601****	0.297	0.371	0.422*	0.343	0.707***	3.485****
(%)			(0.000)	(0.214)	(0.135)	(0.090)	(0.172)	(0.006)	(0.000)
Age					-1.567****	-1.438****	-0.438*	-0.245	-0.544**
(log)					(0.000)	(0.000)	(0.094)	(0.351)	(0.046)
Life expectancy					-0.654	-0.623	-0.523	-1.665***	-1.541***
(log)					(0.189)	(0.222)	(0.313)	(0.002)	(0.004)
Nb. Doctors					0.000212	0.000290	0.000254	0.000208	0.000247
(100,000 habitants)					(0.226)	(0.111)	(0.162)	(0.245)	(0.170)
Density						0.0228*	0.0241**	0.0355***	0.0409****
(log)						(0.058)	(0.048)	(0.004)	(0.001)
Area (Rural)						-0.0921	-0.158**	-0.0557	-0.166**
(%)						(0.229)	(0.043)	(0.476)	(0.044)
Migration						0.619****	0.729****	0.498****	0.474****
(%)						(0.000)	(0.000)	(0.000)	(0.000)
Commuting						-0.175	-0.194	-0.203	-0.0891
(%)						(0.170)	(0.127)	(0.108)	(0.513)

Overcrowding (%)							0.455**** (0.001)	0.526**** (0.000)	0.484**** (0.000)
Water access (No) (%)							0.458**** (0.001)	0.514**** (0.000)	0.519**** (0.000)
Favela (%)							0.609** (0.024)	0.420 (0.114)	0.226 (0.395)
Vote Bolsonaro (%)								1.086**** (0.000)	1.078**** (0.000)
Nb. days without lockdown (log)								0.000803 (0.159)	0.000655 (0.250)
Informal worker (%)									2.307**** (0.000)
Informal*Auxilio E.									-8.737**** (0.000)
Test (per 100,000 inhab.)	0.000143**** (0.000)	0.000151**** (0.000)	0.000147**** (0.000)	0.000165**** (0.000)	0.000151**** (0.000)	0.000161**** (0.000)	0.000156**** (0.000)	0.000164**** (0.000)	0.000166**** (0.000)
Nb. days pandemic (log)	0.951**** (0.000)	1.022**** (0.000)	0.909**** (0.000)	0.935**** (0.000)	0.817**** (0.000)	0.810**** (0.000)	0.771**** (0.000)	0.699**** (0.000)	0.699**** (0.000)
Constant	2.420**** (0.000)	-2.218**** (0.000)	0.0797 (0.758)	-3.015**** (0.000)	6.841*** (0.001)	6.409*** (0.003)	2.981 (0.200)	8.030**** (0.001)	7.471*** (0.002)
lnalpha									
_cons	-0.411**** (0.000)	-0.428**** (0.000)	-0.427**** (0.000)	-0.480**** (0.000)	-0.496**** (0.000)	-0.501**** (0.000)	-0.507**** (0.000)	-0.520**** (0.000)	-0.524**** (0.000)
N	5481	5471	5346	5331	5331	5262	5260	5259	5259

p-values in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.00$

Table A5: Change in factors associated with rate of confirmed cases over time (per 100,000 inhabitants; NB model)

	Confirmed Cases									
	1,000,000 (June 21)		**2,000,000** (July 17)		**3,000,000** (August 11)		**4,000,000** (September 3)		**5,000,000** (October 11)	
Race (White)	-0.23	*	-0.66	****	-0.69	****	-0.52	****	-0.45	****
Sex (Male)	0.39	ns	1.89	ns	2.10	*	1.99	*	1.23	ns
Higher education	-4.81	****	-3.95	****	-3.84	****	-2.55	***	-1.62	**
GDP/cap (log)	0.34	****	0.27	****	0.22	****	0.21	****	0.20	****
Poverty (AE)	4.75	****	3.73	****	3.49	****	3.73	****	3.87	****
Age (log)	1.49	****	0.39	ns	-0.54	**	-0.64	**	-0.61	**
Life Expectancy (log)	-3.17	****	-2.03	****	-1.54	***	-2.08	****	-2.51	****
Nb. Doctors (100,000 h)	0.00	ns	0.00	ns	0.00	ns	0.00	ns	0.00	**
Density (log)	0.07	****	0.06	****	0.04	****	0.02	*	-0.01	ns
Area (Rural)	0.10	ns	-0.12	ns	-0.17	**	-0.22	***	-0.23	***
Migration	0.58	****	0.60	****	0.47	****	0.45	****	0.38	****
Commuting	-0.02	ns	-0.07	ns	-0.09	ns	-0.04	ns	-0.07	ns
Overcrowding	1.82	****	0.98	****	0.48	****	0.42	***	0.33	***
No Water Access	1.43	****	0.94	****	0.52	****	0.46	****	0.34	***
Favela	1.06	***	0.72	**	0.23	ns	-0.12	ns	-0.04	ns
Vote for Bolsonaro	0.84	****	1.00	****	1.08	****	1.01	****	0.89	****
Nb. days without measure	0.00	****	0.00	***	0.00	ns	0.00	ns	0.00	ns
Informal worker	3.06	****	2.66	****	2.31	****	2.08	****	1.84	****
Informal *Auxilio Em. (AE)	-14.27	****	-10.22	****	-8.73	****	-9.06	****	-8.36	****
Tests (100,000h)	0.00	****	0.00	****	0.00	****	0.00	****	0.00	****
Nb. Days of Covid-19	0.50	****	0.61	****	0.70	****	0.80	****	1.03	****
Lnalpha_cons	-0.11	****	-0.33	****	-0.52	****	-0.62	****	-0.72	****
Nb. Observations	**4,707**		**5,230**		**5,259**		**5,268**		**5,259**	

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

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

Note: A negative binomial (NB) model is used for estimation.

Table A6- Factors associated with mortality and infection rates: Results of the NB panel model
(from 21 June to 11 October 2020)

	Mortality rate (per 100,000)			**Confirmed Cases** (rate/100,000)		
	Panel	Panel +time trend	Panel +time trend (State fixed effect)	Panel	Panel +time trend	Panel +time trend (State fixed effect)
Race (White)	-1.04 ****	-6.58 ****	-7,05 ****	-0.33 ****	-2.01 ****	-2,72 ****
Race * Ti		1.30 ****	1,40 ****		0.41 ****	0,50 ****
Sex (Male)	-14.01 ****	-14.68 ****	-9,75 ****	-2.87 ****	-2.30 ***	0,77 ns
Higher education	4.75 ****	4.44 ****	3,15 ***	-1.87 ***	-1.28 **	-2,52 ****
GDP/cap (log)	0.06 *	0.06 *	0,04 ns	0.16 ****	0.15 ****	0,18 ****
Poverty (Auxilio E)	0.34 ns	2.36 **	3,06 ***	0.96 ****	-0.19 ns	0,35 ns
Poverty (AE) * Ti		-0.51 **	-0,84 ****		0.23 *	0,01 ns
Age (log)	-2.56 ****	-2.62 ****	-2,89 ****	1.82 ****	1.80 ****	1,47 ****
Life expectancy (log)	-1.49 **	-0.71 ns	4,44 ****	-2.40 ****	-2.07 ****	0,07 ns
Nb. Doctors (100,000 h)	0.00 ****	0.00 ns	0,00 ns	0.00 ns	0.00 ns	0,00 ns
Density (log)	0.30 ****	0.30 ****	0,32 ****	0.07 ****	0.08 ****	0,09 ****
Area (Rural)	-0.93 ****	-1.10 ****	-1,20 ****	0.04 ns	-0.04 ns	-0,08 ns
Migration	-0.12 ns	-0.21 *	-0,78 ****	0.72 ****	0.64 ****	0,57 ****
Commuting	-1.27 ****	-1.54 ****	-1,17 ****	-0.19 **	-0.18 **	0,00 ns
Overcrowding	1.84 ****	2.39 ****	1,35 ****	1.32 ****	1.46 ****	0,50 ****
No Water Access	0.22 ns	0.99 ****	0,46 **	0.33 ****	0.73 ****	0,13 ns
Favela	-0.99 ****	14.31 ****	12,01 ****	0.91 ****	7.21 ****	6,61 ****
Favela * Ti		-2.44 ****	-2,31 ****		-1.22 ****	-1,35 ****
Vote for Bolsonaro	1.28 ****	-0.39 ns	0,37 ns	0.57 ****	-1.67 ****	-1,00 ****
Vote for Bolsonaro * Ti		0.37 ****	0,29 ****		0.52 ****	0,41 ****
Nb. days without measure	0.00 ****	0.00 ****	0,00 *	0.00 ****	0.00 ****	0,00 ****
Informal worker	0.36 ns	1.19 ns	1,73 **	-0.06 ns	3.80 ****	4,26 ****
Informal worker * Ti		-0.13 ns	-0,17 ns		-0.88 ****	-0,90 ****
Nb. Days Covid-19 (Ti)	0.96 ****	0.49 ****	0,47 ****	0.86 ****	0.74 ****	0,76 ****
Constant	13.04 ****	12.59 ****	-11,92 ****	-3.47 **	-4.50 ***	-13,89 ****
ln_r	-0.34 ****	-0.33 ****	-0,29 ****	0.57 ****	0.57 ****	0,75 ****
ln_s	0.56 ****	0.43 ****	0,54 ****	4.99 ****	4.91 ****	5,15 ****
N	25,841	25,841	25,841	25,723	25,723	25,723

Sources: Ministry of Health, IBGE, Facebook; authors' calculations.
[*] $p < 0.10$. [**] $p < 0.05$. [***] $p < 0.01$. [****] $p < 0.001$
Note: A negative binomial (NB) model is used for estimation.

Table A7- Change in the effects of five factors considering the average level of T_i for each date t
(panel + time trend)

Mortality rate	**α** (X)	**h** (T*X)	**mean**	**21 June**	**17 July**	**11 Aug.**	**3 Sept.**	**11 Oct.**
Race (White)	-6.58 ****	1.30 ****	-0.96	-1.87	-1.53	-0.88	-0.52	-0.12
Poverty (Auxil. Emer.)	2.36 **	-0.51 **	0.15	0.51	0.38	0.12	-0.02	-0.18
Favela	14.31 ****	-2.44 ****	3.74	5.46	4.81	3.59	2.91	2.17
Vote for Bolsonaro	-0.39 ns	0.37 ****	1.23	0.97	1.07	1.26	1.36	1.48
Informal worker	1.19 ns	-0.13 ns	0.62	0.71	0.67	0.61	0.57	0.53

Confirmed cases	α (X)	h (T*X)	mean	21 June	17 July	11 Aug.	3 Sept.	11 Oct.
Race (White)	-2.01 ****	0.41 ****	-0.24	-0.53	-0.42	-0.22	-0.11	0.02
Poverty (Auxil. Emer.)	-0.19	0.23 *	0.82	0.66	0.72	0.84	0.90	0.97
Favela	7.21 ****	-1.22 ****	1.91	2.77	2.44	1.83	1.49	1.12
Vote for Bolsonaro	-1.67 ****	0.52 ****	0.59	0.23	0.37	0.63	0.77	0.93
Informal worker	3.80 ****	-0.88 ****	-0.01	0.61	0.37	-0.07	-0.31	-0.58
Time trend : Average level (ln T_{it})			*4.33*	*3.63*	*3.89*	*4.39*	*4.67*	*4.98*

Sources: Ministry of Health, IBGE, Facebook; authors' calculations.
* $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$. **** $p < 0.001$

Table A8: Socioeconomic correlations over time (PC1991, 2000 and 2010) and PNAD-C

	Population Census			Population Census vs PNAD-C & CAGED		
	2010-2000	2000-1991	2010-1991	2019-2010		2019-2010
Male rate	0.788	0.788	0.765	0.803	PNAD-C	
Higher education	0.884	0.916	0.843	0.970	White	0.987
Life expectancy	0.888	0.937	0.846	-	Age	
Poverty	0.884	0.916	0.843		Own account	0.447
Average income	0.919	0.913	0.859	0.970	Unemployed	0.787
Overcrowding rate	0.928	0.908	0.842		Inactive	0.624
Access to water	0.775	0.396	0.560		CAGED	
Working-age population	0.998	-	-		Formal worker	0.756
Youth in informal jobs	0.929	-	-			

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

Table A9: Results using measures of excess mortality. Factors associated with the mortality rate (per 100,000 inhabitants)

	Linear regression model using measures of excess mortality					
	March-May 2020 / mean 2017-2018		**Jan-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	**
Higher 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
Commuting	-18.07	ns	-18.09	ns	-26.33	***
Overcrowding	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	**
Informal *Auxilio Emer. (AE)	-434.44	**	-674.46	***	-436.79	***
Nb. days of Covid-19	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.
* $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$. **** $p < 0.001$
Notes: Variables in excess mortality include negative data retained to make allowance for measurement problems in previous years.