The Racial Income Gap and Mortality: Evidence from Brazil

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Abstract

In this paper, we use Census and mortality data to investigate the relationship between racial income inequality and death rates across 5,565 municipalities in Brazil. We find that a 1% increase in the racial income gap is associated with a 0.5% higher mortality rate for Non-Whites aged 5-49. This result is driven by differences in homicide rates among youth and young adults, and infectious diseases in middle-aged, particularly females. Our findings align with previous studies, indicating that living conditions, such as sanitation and exposure to violence, are the main mechanisms linking the racial income gap to mortality rates in Brazil.

Keywords: Mortality Inequality, Income Inequality, Racial Inequality, Brazil

JEL: H75, I14, I15, J15

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1 Introduction

In recent decades, there has been a significant rise in the number of studies examining the relationship between income inequality and health outcomes, with existing evidence suggesting that health tends to be worse in more unequal societies (Pickett and Wilkinson, 2015). Large differences in income can affect health through various pathways, such as underinvestment in public services like education and healthcare, the erosion of social capital, and the induction of stress from unfavorable social comparisons (Kawachi and Kennedy, 1999). However, much less is known about the association between large income differences between racial groups and health outcomes. These racial income disparities are prevalent in countries like the U.S. and Brazil, where historical factors, such as slavery, contribute to the overrepresentation of Blacks in low-income groups (Kawachi et al., 2005).

This paper aims to fill this gap by using Census data in 2010 and vital statistics 2009-2011 to investigate how race-based income inequality is associated with death rates in Brazil. We use Census data to compute the average income gap between White and Non-White individuals for each of the 5,565 Brazilian municipalities, and use it as a measure of the racial income gap. The reasoning is that the level of income for a particular racial group living in a city is not the only relevant factor to consider when analyzing mortality outcomes. It is also important to take into account the size of the gap between the income of racial groups in the same municipality. For example, when there is a large racial gap in a municipality, Non-White individuals may face additional challenges in accessing healthcare, living in quality housing, being exposed to more environmental hazards, and having higher levels of stress, all of which can have negative effects on their health and well-being.

Examining the relationship of race-based income inequality with mortality outcomes is a challenging task. A first concern is that the positive correlation between mortality rates with income inequality is confounded by the effects of racial composition in a given place (Deaton and Lubotsky, 2003). However, more recent studies indicate that ethnic heterogeneity, at least in the context of the US, does not confound the relationship between income inequality and health (Ash and Robinson, 2009). This concern does not apply to the Brazilian setting, where both White and Non-White incomes decrease as the percentage of Non-Whites in a municipality increases, and the income gap between these groups is

narrower in those municipalities. Previous research notes that the connection between income inequality and health outcomes is more pronounced in larger geographic areas (Subramanian and Kawachi, 2004; Wilkinson and Pickett, 2006). Given our focus on municipalities, the smallest administrative units in Brazil, we anticipate more modest effects.

Our results indicate two main findings: one in relation to the link between mortality and race-based income inequality across municipalities, and the second further clarifies the mechanisms linking the racial income gap and mortality rates. First, our findings indicate that larger income gaps between races are associated with higher mortality rates among Non-White individuals. We also document that this association is strongest for Non-White adults aged 20 to 34, especially males. For example, our results suggest that a 1 percent increase in the racial income gap is associated with 0.5 percent higher death rates among Non-White individuals of both genders at ages 20 to 49, compared to their White counterparts. We also find that this gradient decreases among older adults (aged 50 or older) which is consistent with lower poverty rates among this age group, and with selection among Non-Whites in older ages (OECD, 2013; Preston and Elo, 2006).

We investigate the causes of death that drive differences in mortality rates between races in Brazil. We follow previous literature, e.g., Currie and Schwandt (2016), and rank Brazilian municipalities according to their racial income gap. We find that the leading causes of death driving our results for adults aged 20-49 are homicides and infectious diseases. Our results show that among both males and females, there is no association between the racial income gap and cardiovascular diseases, which are often used as an indicator of healthcare access. We attribute this to the sharp decline of 46% in the percentage of adult smokers in Brazil over the period of 1989-2013, irrespective of race (Malta et al., 2020). In summary, our findings indicate that in Brazil, living conditions such as sanitation and exposure to violence are the primary mechanisms through which the racial income gap is associated with mortality rates.

We provide robustness checks to address concerns about the small sample sizes from certain demographic groups that could lead to an excess of zeros (e.g., in the number of deaths) and bias our results. We take two approaches. First, we run estimations using an aggregation of similar contiguous municipalities in Brazil (micro-region level) instead of the municipality level. Second, we exclude cells with less than 500 individuals when estimating regressions. Finally, to further test the robustness of our findings, we distribute deaths with

missing information on race following the same approach as in Chiavegatto Filho et al. (2014), exclude regions with lower death registry coverage, and run placebo tests using per capita income. Overall, these robustness checks do not affect our core findings.

The remainder of the paper is organized as follows. An overview of the previous literature is in Section 2. Section 3 discusses the data and methods while Section 4 reports our main results. We discuss results with respect to the main causes of death in Section 5. Section 6 present our robustness checks and Section 7 concludes.

2 Background

In the 2010 Census, 97 million people (49%) in Brazil self-reported their race as mixed-race or Black, making Brazil the country with the largest share of African descendants outside of Africa (Alberto, 2008; IBGE, 2019). The data consistently indicate a pattern of racial segregation within the country, with Blacks and mixed-race differing significantly from Whites, particularly concerning educational attainment and income levels (Pereira and Queiroz, 2016; IBGE, 2019). For example, the average monthly income of Whites was 84.50% higher than that of Blacks, and 81.96% higher than that of mixed-race individuals (Chiavegatto Filho et al., 2014), suggesting that race is a major SES indicator in Brazil (Kawachi et al., 2005).

These findings lend support to the rationale behind grouping *Pardos* (mixed-race) and Blacks as Non-White, considering their similar profiles in income, education, and other SES factors. Indeed, this has been the standard approach in the demographic and economic literature investigating the relationship between race and various outcomes in Brazil such as education, health and employment (Marteleto, 2012; Marteleto and Dondero, 2016; Botelho et al., 2015).

Previous studies have found that households headed by Non-White individuals face a significantly higher risk of poverty than their White counterparts (Ferreira et al., 2003). However, when other variables such as education and location are taken into account, the association of race with poverty becomes statistically insignificant suggesting that both individual factors (e.g., socio-economic position) and structural-level factors (e.g., municipality) are closely linked with economic resources.

Recent evidence also suggests that the income gap between Black and White individuals

is larger in Brazil than in the US. Specifically, the average income of Black individuals in Brazil is about 45% lower than that of Whites, while in the US, this gap is about 36% lower (Chiavegatto Filho et al., 2014; Bureau, 2013). The strong association between race/ethnicity and SES in Brazil, however, does not appear to be associated with major differences in life expectancy by race/ethnicity in the country. For example, Chiavegatto Filho et al. (2014) find that Blacks in Brazil have a life expectancy in 2010 that was about 0.99 lower than whites for men and 1.22 years lower for women, while in the US this difference was about 5.5 and 3.7 years for males and females, respectively.

2.1 Racial disparities in health

There is still much debate on how to interpret racial disparities in health, as the underlying mechanisms and mediating factors are complex and difficult to disentangle. Previous research has explored various factors that may contribute to these disparities, including individual health behaviors, the relationship between race/ethnicity and socio-economic status, and structural-level factors associated with racism and discrimination. For instance, socio-economic status may increase access to healthcare which improves health outcomes (Helgadottir et al., 2006), while structural-level factors related to racism have been proposed as a major driver of health inequalities in the US (Zambrana and Williams, 2022). For example, Geronimus et al. (2006) suggests that Black women experience greater physiological distress due to a combination of chronic material deprivation and daily discrimination compared to White women.

Our study relates more closely to Siddiqi et al. (2016), who documented that income inequality appears to be a more significant predictor of racial disparities in infant mortality rates in the US. Our paper also engages with recent studies highlighting the importance of location externalities on health outcomes and longevity, as individuals living in more affluent areas tend to have better access to infrastructure such as sanitation, lower air pollution, and better healthcare facilities (Chetty et al., 2016). Our analysis provides evidence on how income gaps between races within small geographical areas are associated with mortality.

Previous studies for Brazil highlight a strong connection between race and health disparities in the country. For example, according to Perreira and Telles (2014), there is a noticeable difference in self-rated health status based on skin color, which is associated with low socio-

economic status and increased exposure to racial discrimination. Trujillo et al. (2009) found that elderly White individuals in Brazil report better health than Non-White seniors, with differences attributed to past socio-economic factors such as living in rural areas during early childhood. Furthermore, research by Chiavegatto Filho et al. (2014) suggests that differences in life expectancy in 2010 by race were smaller in Brazil compared to the United States.

3 Data and Methods

We use two data sources that together allow us to compute death rates and income inequality by race. First, we use data from the Mortality Information System (Sistema de Informação de Mortalidade, SIM) and the 2010 Census from the Brazilian Statistical Agency IBGE (Instituto Brasileiro de Geografia e Estatística). The SIM is a centralized death registers system that covers more than 95% of deaths in Brazil. Death certificates (DC) are standardized and distributed to the entire country by the Ministry of Health. The document is completed by a doctor or by two qualified people who have witnessed and/or verified the death. The DC's are collected by the Municipal or State Health Department at the Health Facility and the data is entered into the system. Death records in Brazil carry information about the deceased's place of birth, age, sex, race, marital status, and municipality of residence.

Second, we use the 2010 Brazilian Census to construct multiple variables at the municipality level. Municipalities are the smallest administrative units in Brazil and their population may vary substantially — from about 800 people to over 12 million. We construct population counts and average income estimates by municipality, age and race. A binary category of race is created as follows. Individuals that self-reported[1] as being white are defined as white while Non-Whites include blacks and mixed race (*Negros and Pardos*). We code both Pardos (mixed-race) and Blacks as Non-White due to their similar profiles in terms of income, education, employment, and other socio-economic factors (IBGE, 2019). We drop observations for other racial categories (e.g., Asian, indigenous, etc.) which consist of less than 1% of the national population.

Municipality-level controls in our models include employment rates, the fraction of high

[1] race is self-reported in the Census while among the deceased, race is assigned by the person filling out the death certificate.

school dropouts, poverty rates, the share of urban population, the share of young adults (ages 18 to 30), average years of schooling, household size, average monthly household income, the share of whites, and governmental spending and revenue per capita (see Table 1). By including these variables in the regression model, we control for potential confounding factors affecting the link between race and death rates.

We calculate death rates as the ratio of deaths over the population by age, sex, and race for each municipality. To avoid excess zeros in the total number of deaths coming from very small municipalities, we constructed age and sex-specific death rates using a three-year moving average (2009-2011) of SIM data for four age groups: 0-4, 5-19, 20-49 and 50 or older.

An advantage of working with these data is that the samples from both data sources are perfectly matched at the municipal level since the geographic identifiers provided in the SIM and Census data are identical. To smooth the size of municipalities, we follow Currie and Schwandt (2016) and divide the six largest municipalities (with more than 2 million inhabitants) in our sample into five smaller groups, each of equal size and with identical death rate[2].

As noted above, we use a measure of race as a dichotomous variable Whites and Non-Whites (e.g, pardos and Blacks). Previous evidence indicates that socioeconomic progress during the past three decades has led to substantial changes in the social status of Black individuals (Telles and Lim, 1998; Marteleto, 2012). This transformation has resulted in a clear dichotomy between White and non-White populations across various dimensions associated with health disadvantages, including income, education, and employment. We compute the difference in average monthly income between Whites and Non-Whites for each municipality in Brazil. We consider this racial income gap as a measure of inequality across racial/ethnic groups in Brazil and investigate its association with death rates.

We estimate the following equation separately for each sex and age group:

$$\log(Y_{ri}) = \alpha + \beta_1 \log(Dif_i) + \beta_2 Race + \beta_3 \log(Dif_i) \times Race + \beta_4 X_{ri} + \epsilon_{ri} \qquad (1)$$

where Y_{ri} is the mortality rate of race r in municipality i, X is a vector of covariates at the municipality level (see above for municipality-level controls), *Race* is a binary variable (0

[2]These municipalities are Belo Horizonte, Salvador, Rio de Janeiro, São Paulo, Brasília, and Fortaleza.

= Whites, 1 = Non-Whites), Dif_i is the income gap between Whites and Non-Whites in a given municipality i, and ϵ is the error term. Adding a dummy variable for race controls for the overall association of race on the dependent variable, mitigating potential concerns that the interaction effect of income inequality and race is confounded by the effect of race itself. Hence, the effect of income inequality between racial/ethnic groups in the outcome variable is captured by β_3.

Finally, the models are estimated using the population size of each municipality as weights. This ensures that our results are not driven by the population density of municipalities in Brazil. We weight regressions in two ways. First, regressions are weighted by the municipalities' total population, and second, weighted by the population of the racial group in the corresponding municipality (Miller and Paxson, 2006). This implies that when we estimate models for certain demographic groups, we assign less weight to those municipalities with a small share of these racial groups relative to other municipalities. We thus present three sets of results: model (1) has no controls, model (2) adds municipality-level controls and these two models are weighted by the municipality's total population (columns 1 & 2, respectively, in **Tables 2** and **3**), while model 3 is equivalent to model (2) but it is weighted by the racial group population in the corresponding municipality (column 3 in **Tables 2** and **3**).

4 Results

We start by showing the association between average monthly income by race and the per capita income of each municipality in Brazil (**Figure 1**) and the race-based income inequality versus the per capita income (**Figure 2**). These figures show that richer cities (e.g., those with greater income per capita) are also the ones with the largest race-based income inequality between whites and Non-Whites.

Table 1 provides descriptive statistics across the municipalities for the main variables used in our empirical analysis. This table shows that, on average, Non-Whites are more likely to be socio-economically disadvantaged relative to Whites. For example, there is a sizeable income gap between Whites and Non-Whites with a difference of nearly 45% in their average income. In addition, Whites have about 1.2 years more schooling than Non-Whites. In other

demographic variables such as age, gender, household size, and employment rate there are no sizeable differences by race in Brazil.

4.1 Averages by municipality

Regression results using data across all municipalities are shown in **Table 2**. Coefficient estimates suggest that race-based income gaps are associated with greater death rates among Non-Whites relative to Whites across all age groups for both men and women. The magnitude of these coefficients is smaller when regressions are weighted by the racial group population in the municipality (column 3) than when the weights are those from the total population in the municipality (column 2). In either model, the magnitude of the coefficients is quite large for young and middle-aged adults. For example, for males at ages between 5 and 19, a 1% increase in the racial income gap is associated with 0.55% higher Non-White death rates relative to the baseline White mortality (column 3). This magnitude is very similar for people aged 20-49 for males and females, with about 0.5% higher Non-White mortality. These results are less consistent for older adults (aged 50 or older) with no significant results among females (column 3) and a relatively small higher mortality among Non-White males (0.1%).

To lend more interpretability to our results, we provide a back-of-the-envelope calculation examining the association of the income gap on mortality rates. For example, a 10 percent increase in the income gap is associated with a 5% increase in mortality rates for Non-White males aged 5-49. Given that the average death rate in this group is 5.44 deaths per 100,000 population, the calculation yields a 0.272 increase in the death rate associated with the income gap. If the average number of deaths for this group is 26, the additional deaths related to the 10 percent increase in the income gap can be estimated as 7.072. Therefore, this increase in the race-based income gap is associated with approximately 7 additional deaths among Non-White males aged 5-49.

To summarize the findings from **Table 2**, there is evidence that a large racial income gap at the municipality level is associated with higher Non-White mortality, especially among individuals between ages 5-49. Moreover, the F-test shown at the bottom of the table [3]

[3]The F-test we show is testing the hypothesis that the interactions of race and race-based income inequality are jointly significantly different from zero.

confirms that Non-Whites experienced higher death rates than Whites in municipalities with a large difference in income between Whites and Non-Whites in Brazil.

4.2 Averages by groups

If differences in earnings across gender and age groups vary differently among Whites and Non-Whites, we would be underestimating the association between race-based inequality and mortality for some groups and overestimating for others when looking at this link across all municipalities. Therefore, instead of using average earnings by race and municipality, we now compute the average earnings defined by gender, age, and race by municipality (e.g., average earnings for Non-White females ages 20-34 in a given municipality). In particular, we aggregate data focusing only on adults ages 20 to 34, 35 to 44, 45 to 54, and 55 to 64 and estimate a model similar to equation (2).

Table 3 displays our estimates. As before, we estimate separate models by sex with models being weighted by the total population in the municipality (column 2) or by the racial group population in the municipality (column 3), respectively. These results confirm that large racial income gaps are associated with higher Non-White mortality in Brazil. In contrast to the results across all municipalities (Table 2), the magnitude of the coefficients is very similar between models 2 and 3, except for those aged 20-24. However, the table shows a stronger association between the racial income gap and mortality among younger ages with income gradients declining with age. For example, at ages 20 to 34, the association between race-based income inequality and mortality is nearly four times stronger for males than for females: the coefficient indicates that a 1 percent increase in the racial income gap is associated with about 0.6% higher Non-White mortality among males and about 0.2% higher mortality among females. This association is also significant among people aged 35-44 and 45-54 (model 3) although the magnitude is much smaller (less than 0.2% higher mortality for a 1 percent increase in the racial income gap). Nonetheless, there is no clear evidence of a significant link between race-based income inequality and mortality among older individuals in Brazil.

4.3 Micro-region estimations

The small sample sizes from certain demographic groups in very small municipalities could lead to an excess of zeros in the number of deaths and bias our results. In this section, we assess the potential bias in our estimates by aggregating the data at the regional level. We show estimates of our models using 413 Brazilian micro-regions as the unit of analysis. Micro-regions are an aggregation of similar contiguous municipalities in Brazil. The mapping between municipalities and micro-regions is periodically updated by IBGE and they have been widely used as the units of observation.

There are at least two advantages of using micro-regions as the unit of analysis. First, it eliminates the zeros in death counts since we are working with aggregated data. Second, aggregating the data reduces the likelihood of having 'noisy' data (e.g., erratic rates) since small municipalities tend to have a low number of deaths. Nonetheless, the aggregation may lead to some disadvantages. For example, we are working with a considerably smaller sample size which could decrease the statistical power to detect differences in our results. In addition, the higher level of data aggregation considerably increases heterogeneity since micro-regions often include very different, but still contiguous, municipalities.

Table A1 in the Appendix shows our results for the 413 micro-regions. As expected due to the small units of analysis, the magnitude of the coefficients are smaller, relative to those using municipality-level analysis (Table 2), and the significance of the coefficients is also reduced. Although the relationship between the race-based income gap and mortality is no longer significant for children below age 5, for youths (5-19) and young adults (20-49), the coefficients are remarkably similar to those in **Table 2** and **Table 3**. They indicate that a 1% increase in the racial income gap is associated with higher Non-White mortality (0.63% for males and 0.46% for females, column 3). Both are statistically significant at the 10%-level in regressions weighted by the racial composition within municipalities (column 3). For ages 20 to 49, results are less consistent with some significant results among females (columns 2 & 3) but not among males (except for model 2). In contrast to previous results, our estimates by micro-regions suggest that Non-White mortality is significantly associated with the racial income gap among older adults (aged 50 and above). Coefficient estimates are very similar across genders and of similar magnitude regardless of the weights used in the regression. We take these results as additional evidence that race-based income inequality

harms Non-Whites' risk of death among young adults.

5 Trends by causes of death

The results so far focused on overall mortality. In this section, we examine the leading causes of death driving our previous results. We follow Currie and Schwandt (2016) and rank Brazilian municipalities according to their racial income gap. We group municipalities into 20 bins each representing 5% of the population and calculate the 3-year mortality rate for each age group, race and sex in 2010. To help with the interpretation, we have fitted straight lines through the 20 points as seen in **Figures 3 to 7** for females and males, respectively. The y-axis in these graphs shows death rates, while the x-axis depicts the racial income gap ranks (larger values indicate a higher racial income gap inequality). Values for Whites are shown in red and values for Non-Whites in green. By examining the slopes of the regression lines, we can assess the strength of the association between race-based income inequality gradients and death rates. Steeper lines, for example, indicate that places with higher levels of racial income inequality have higher mortality.

All causes mortality. The results shown for all causes mortality confirm our previous results, indicating that the racial income gap gradient is small for child mortality (0-4) and at older ages (above 50) for both females and males. Conversely, a larger racial income gap is associated with higher mortality rates for Non-White individuals age 5 to 49, particularly males. Moreover, Non-Whites experienced higher death rates than Whites at any given level of race-based income gap, with the exception of older cohorts above age 50. This result, which has also been found previously in the US has been attributed to the fact that Non-Whites who reach older ages may exhibit a higher level of robustness due to selection mechanisms (Chiavegatto Filho et al., 2014; Corti et al., 1999). In **Figures 4** to **7**, we display death rates for specific cause mortality: homicides, infectious diseases, cardiovascular diseases, and respiratory diseases.

Homicides and infectious diseases. Figure 4 and **Figure 5** highlight that infectious diseases and homicides are the primary factors through which the racial income gap is associated with racial inequality in mortality. For homicides, we observe very steeper slopes for Non-Whites at ages 5-19, while for Whites the lines are consistently flat for both genders.

For the 20-49 cohort, the development is similar, with positive slopes for Non-Whites and negative lines for their Whites counterparts. There is no clear relationship between the racial income gap and homicide rates older cohorts (50+).

Turning to infectious disease mortality, we observe negative or flat slopes for child mortality (0-4), which supports the idea that richest, more unequal cities have a safety net in terms of childcare policies. However, in the 5-19 age groups, the disparity widens, with Non-White males and females showing a strong positive correlation between racial income inequality and mortality. The largests disparities are seen in the 20-49 and 50+ age groups, with Non-White mortality rates significantly increasing with racial inequality rank, especially for females above 50, contrasting with the relatively flat lines for Whites.

Non-White individuals, particularly those with lower incomes, tend to reside in areas characterized by higher crime rates and pollution, rendering them more susceptible to homicides and infectious diseases (Deaton, 2002; Williams and Jackson, 2005).

Cardiovascular and Respiratory diseases. Figure 6, **Figure 7** plot the 3-year mortality rates against the racial income gap in Brazil. For younger cohorts, below age 19, we observe mostly parallel lines with slightly negative slopes for both causes. Conversely, the positive slopes for Non-White males above age 20 suggest that the racial income gap is associated with increasing Non-White mortality due to both respiratory and cardiovascular diseases. For females, the relationship is not that salient, although the slopes are never negative as for their White counterparts. For cohorts above age 50, we observe a positive slope only for males, which could be due to different rates of quitting smoking in Brazil. Between 1989 and 2013, the percentage of smokers in Brazil decreased by 46%, but the percentage of White smokers (11.8%) is smaller than that of Non-Whites (13.6%)(Iglesias et al., 2017; Malta et al., 2015). Interstingly, cardiovascular mortality, which is frequently used as a measure of access to healthcare, is not strongly associated to the racial income gap.

Cancer mortality. Figure 8 display the results for cancer mortality. In the youngest age group (0-4), mortality rates show a slight increase with racial inequality rank.. In the 20-49 age group, Whites have greater mortality in level and also steeper slopes. This fact can be explained by the fact that, as shown in **Figure 1**, the racial income gap increases with per capita income, which usually have more capacity to provide medical diagnose of cancer. The most substantial differences are observed in the 50+ age group, where mortality

rates for Non-Whites increase sharply with racial inequality, particularly for females. In contrast, White mortality rates show a much flatter slope. These patterns highlight the disproportionate impact of racial inequality on older Non-White cohorts through cancer mortality.

6 Robustness Checks

In this section, we provide additional analysis to assess the sensitivity of our findings to missing data on race. In our previous estimations, we excluded all deaths with missing race to provide a first set of estimates about the association between race/ethnic-based income inequality and mortality in Brazil. Previous research found that missing information on race is not random. Instead, deaths are more common among the poor, which are the majority among Non-Whites. We proceed in four steps. First, we consider all of these "missing race deaths" to be from Non-Whites and we input all deaths registers without race information as Non-Whites. Second, we follow the same approach as in Chiavegatto Filho et al. (2014), and proportionally distributed missing race deaths according to the racial composition of people earning less than the minimum wage (38% of deaths as White and 62% as Non-Whites). Third, we also exclude cells with a population of less than 500 people. The resulting sample is nearly 50 percent smaller but it is balanced in terms of race.

Deaths with missing information on race. From all deaths, approximately 6.5% lack a designated race. The highest proportion is found in child mortality (ages 0 to 4) at 10%, decreases to around 6% after age 15 and remains constant in older age groups. **Table A2** in the Appendix reports our estimates when imputing race on death counts under the assumptions described above. All regressions are weighted by the population in each racial group in a given municipality. Columns (1) and columns (2) assume all deaths with missing information on race come from Non-Whites individuals but in addition, models in column 2 exclude cells with population less than 500 people. Column 3 shows models where missing race has been proportionally allocated. Results in Table A2 are consistent with our previous estimations and are also consistent with other evidence that income gradients decrease with age (Miller and Paxson, 2006; Deaton and Lubotsky, 2003).

We find coefficients with similar magnitude across genders among Non-Whites compared

to those in Table 2. These results show a stronger association of race-based income inequality and mortality for female infants and young children. For the age group between ages 5 and 19, however, the coefficients for males are twice as large as their female counterparts. For young adults and middle-aged individuals, both Non-White males and females display positive and statistically significant coefficients indicating a strong association between race-based income disparities and Non-White mortality.

The exclusion of population cells with less than 500 individuals in estimates in column (2) does not have a consistent effect on the parameter estimates, with the exception of the 0-4 age group. Results in column (3) show a slightly greater magnitude of coefficients and these effects are also stronger in the 0-4 age group for both genders. Taken as a whole, these sensitivity analyses support our previous estimates. We see that our results are still very similar to those using the full sample and confirm our previous findings.

Excluding regions with lower death registry coverage. The lower coverage of death registries in some regions of Brazil could cast doubt on the precision of our results. Therefore, we provide additional estimates in which we excluded municipalities from the north and northeast regions that tend to have a somewhat higher death undercount (see Appendix **Table A3**). In addition to being the poorest, the northern and northeast regions are also the most economically unequal regions of the country[4]. Our results are also consistent with our previous estimates (Appendix **Table A3**). We conclude that missing data on race in death counts does not substantially alter our main findings.

Placebo test using per capita income by municipality. As **Figures 1** and **2** show, the richest municipalities are also the ones with the largest income gap between Whites and Non-Whites. The fact that these two variables are correlated could call into question if our results are driven by factors other than the racial income gap. To further test this hypothesis, we provide additional estimations in which we interacted per capita income by municipality with race. **Table A4** in the Appendix reports our results. Coefficient estimates are consistently negative which indicates that per capita income is associated with lower Non-White mortality which runs contrary to our main findings. In summary, these results lend support to the interpretation that the racial income gap is positively associated with higher mortality among Non-Whites. Finally, textbfFigures A1 and **A2** show homicide rates

[4]In 2010, the Gini index for the northern region was 0.608 and 0.627 for the Northeast (IBGE).

and infectious diseases mortality rates using per capita income ranks. In contrast to our previous results which showed steep slopes for Non-Whites and flat slopes for Whites, we observe mostly parallel lines, indicating similar gradients for both racial groups in Brazil.

7 Discussion

This study adds to the ongoing discussion about the link between racial income inequality and mortality (Schwandt et al., 2021). To the best of our knowledge, it is the first to integrate Census and mortality data for Brazil and introduce a straightforward metric for assessing and quantifying income disparities among racial groups at the local level.

We find that income gaps between Whites and Non-Whites are associated with greater mortality rates among Non-Whites in Brazilian municipalities. When analyzing the leading causes of death, our findings indicate that homicides and infectious diseases emerge as the main factors linking racial income disparities and racial differences in mortality. This finding is consistent with previous research showing that health disparities are substantially affected by living conditions, particularly housing (Williams and Collins, 2016).

We document that the strongest adverse effects of the racial income gap are concentrated in the 5-49 age group, presumably the demographic group with greater psychosocial distress due to discrimination and exposure to crime (Kawachi and Kennedy, 1999; Pettit and Gutierrez, 2018). Conversely, we find that the racial income gap is not significantly associated with mortality among older adults (50+). This result may be due to mortality selection, where adverse conditions lead to a more robust group of survivors (Preston and Elo, 2006). Additionally, Brazil's cash transfer program for those over age 64 has successfully reduced poverty in this age group (7.8% vs. 15% in Latin America) (OCDE, 2020), potentially mitigating the impact of income inequality on mortality rates.

Overall, our results suggest that efforts should concentrate on reducing homicides and improving housing conditions in areas with large income differences between Whites and Non-Whites. Finally, the results of our study are in line with previous theoretical works, which examine the ways in which racial/ethnic inequality may affect health outcomes (Swope and Hernández, 2019).

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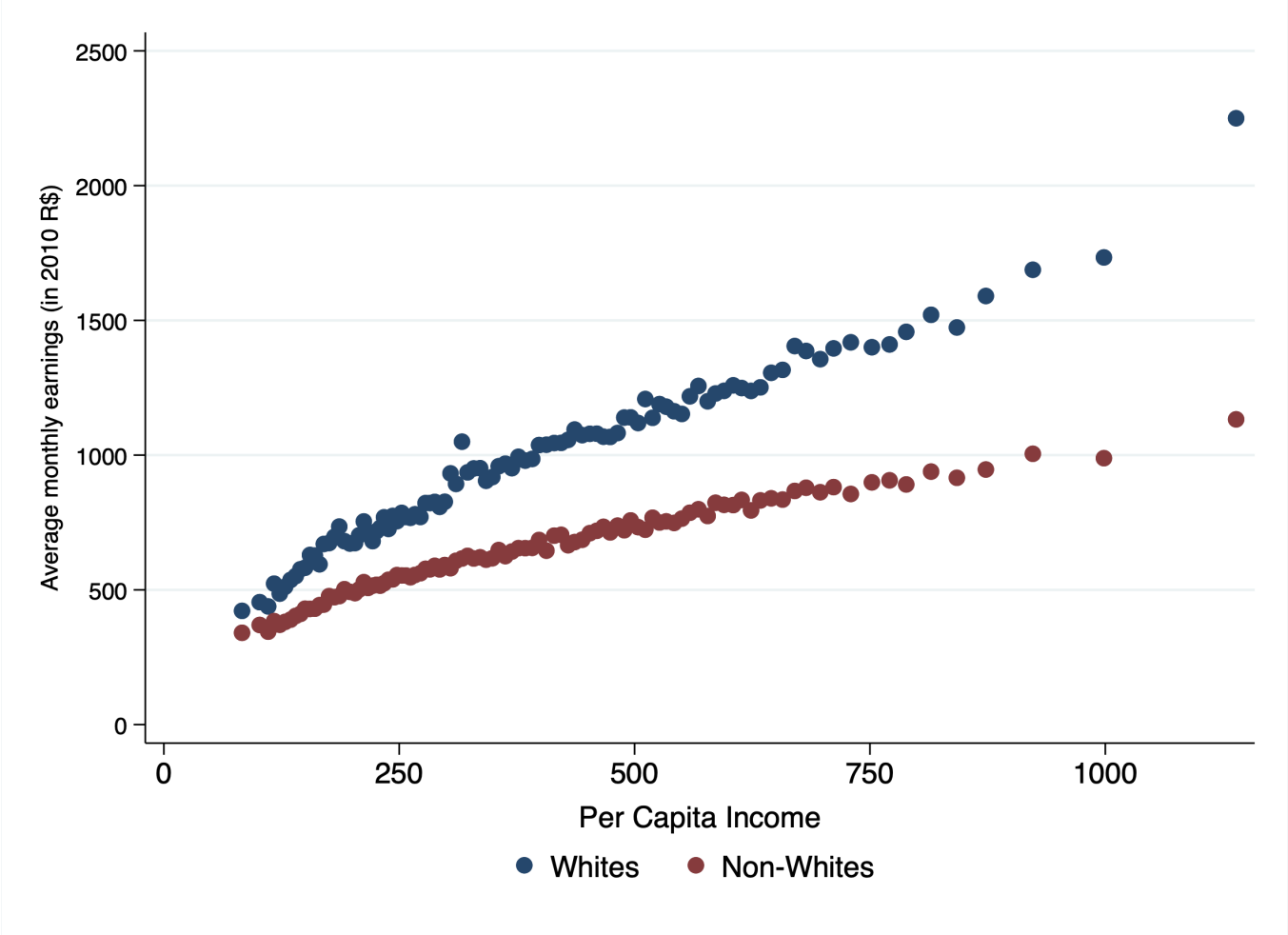
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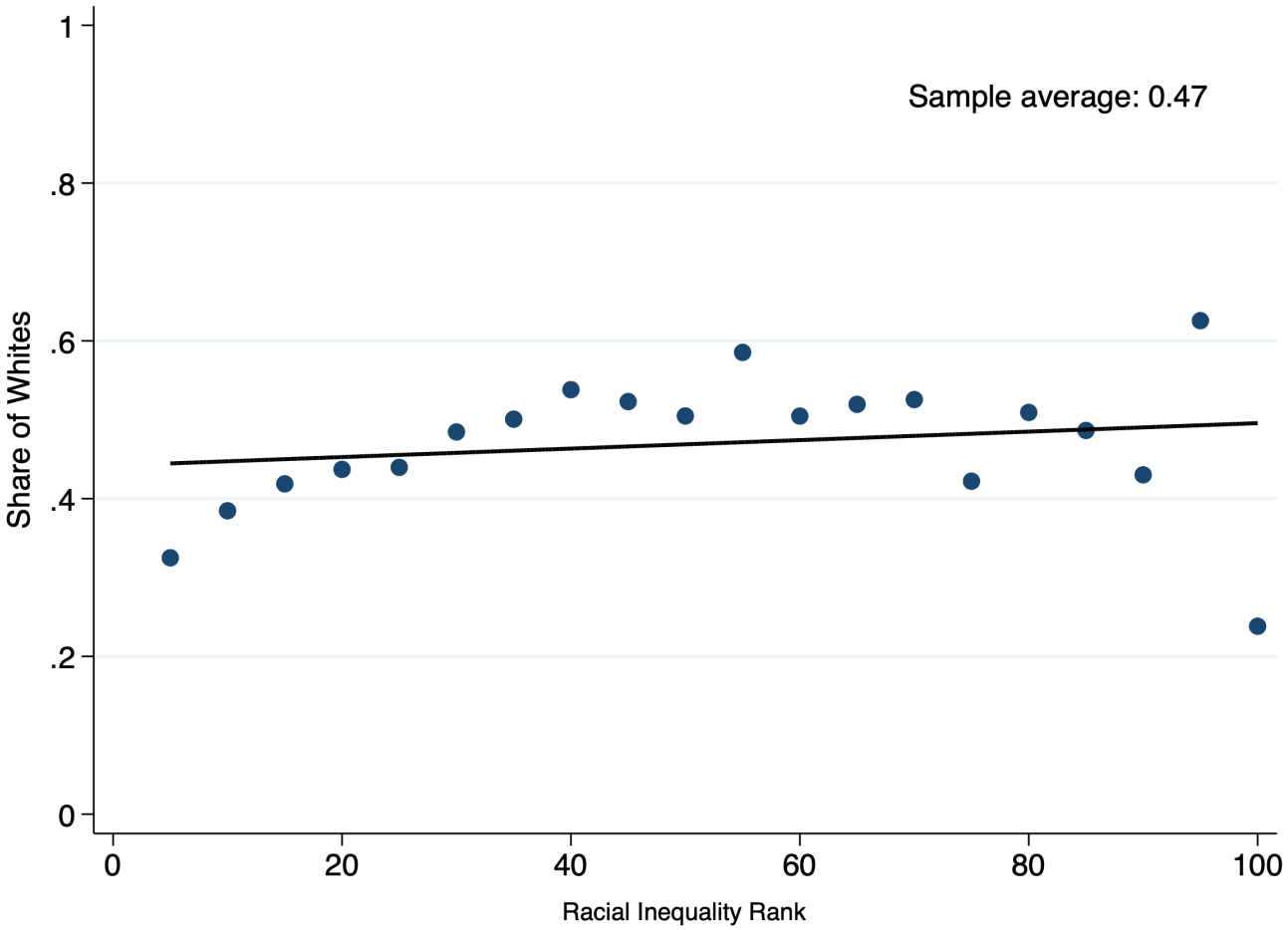
8 Figures

Figure 1: Earnings by Race by per capita income in Brazilian municipalities



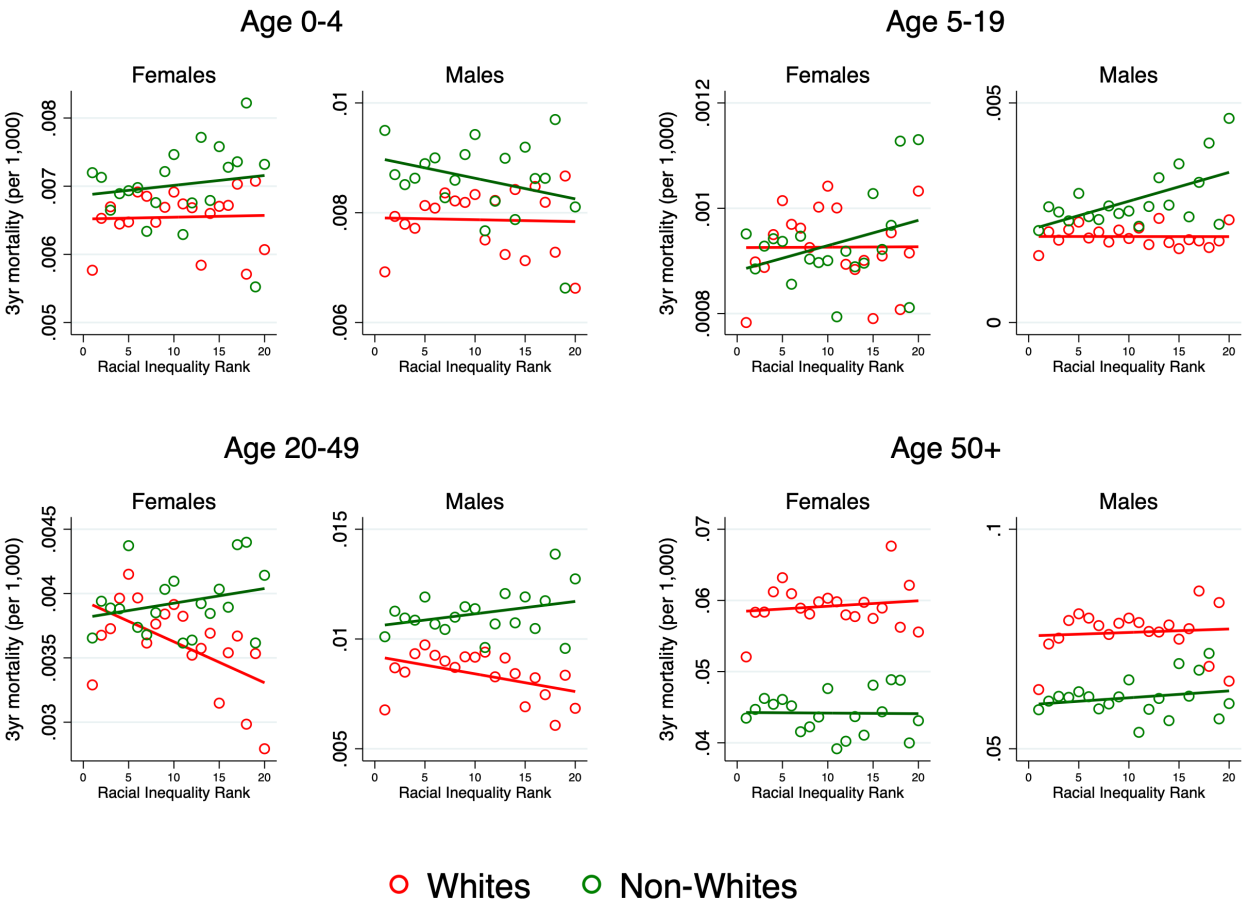
Note: This figure plots the average earnings for Whites and Non-Whites by income per capita across Brazilian municipalities in 2010.

Figure 2: Share of whites by quantiles of racial income gap



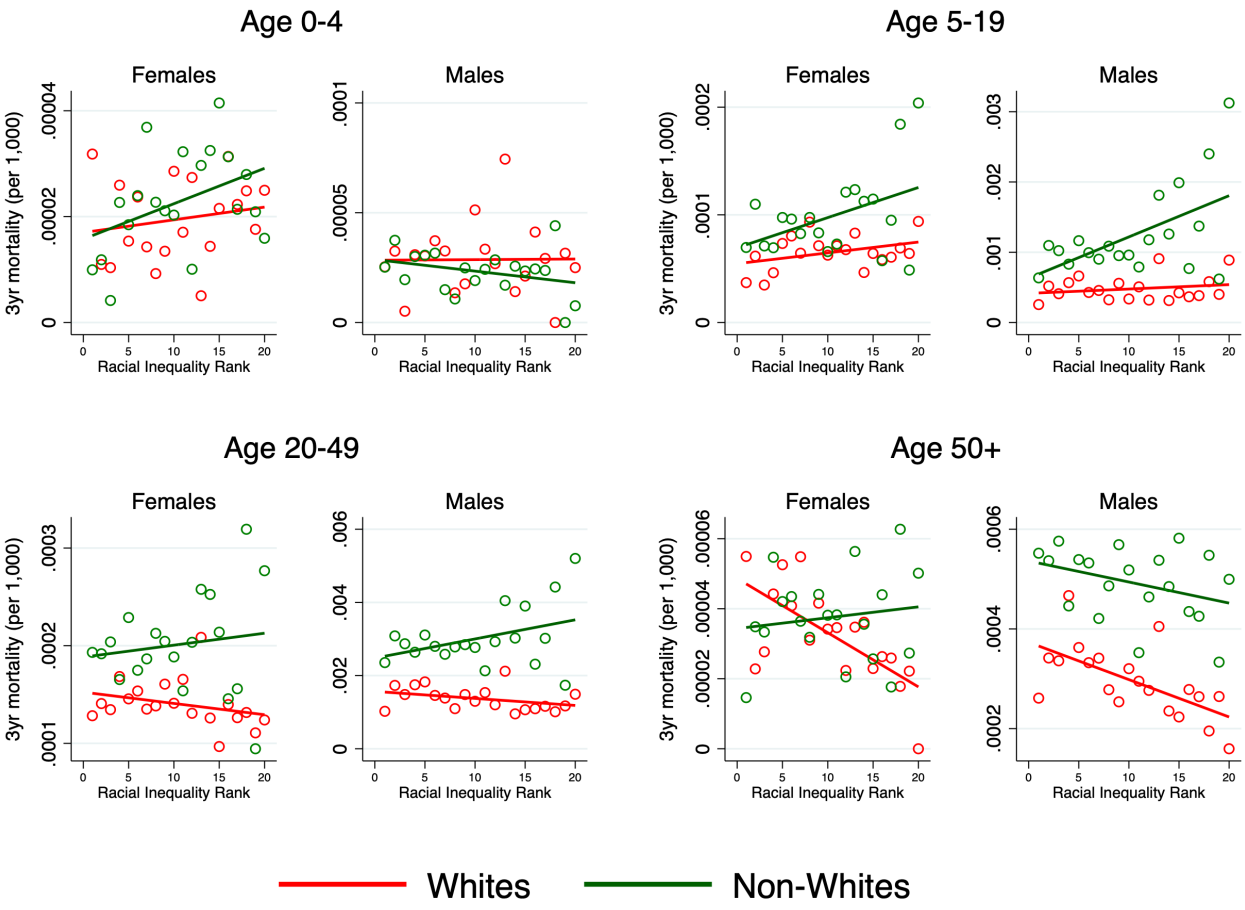
Note: This figure plots the share of Whites across the 20 ventiles of the racial income gap in 5,565 Brazilian municipalities in 2010.

Figure 3: All cause mortality and racial income gap



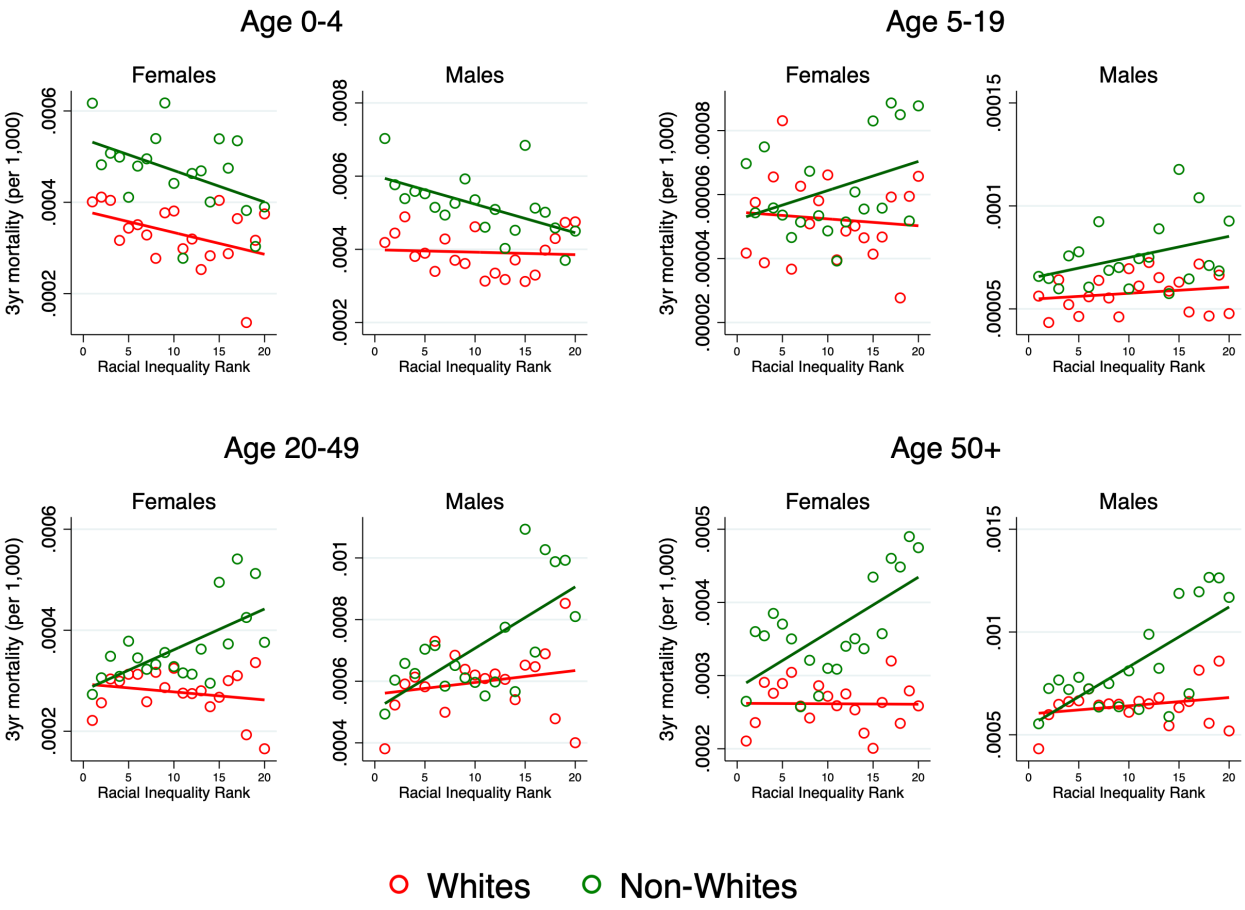
Note: Three-year death rates by racial income gap ventiles across age for females and males. Average 3-year death rates are plotted across groups of Brazilian municipalities. Each bin represents a group of municipalities with about 5% of the overall population in 2010. Straight lines provide linear fits.

Figure 4: Homicides mortality and racial income gap



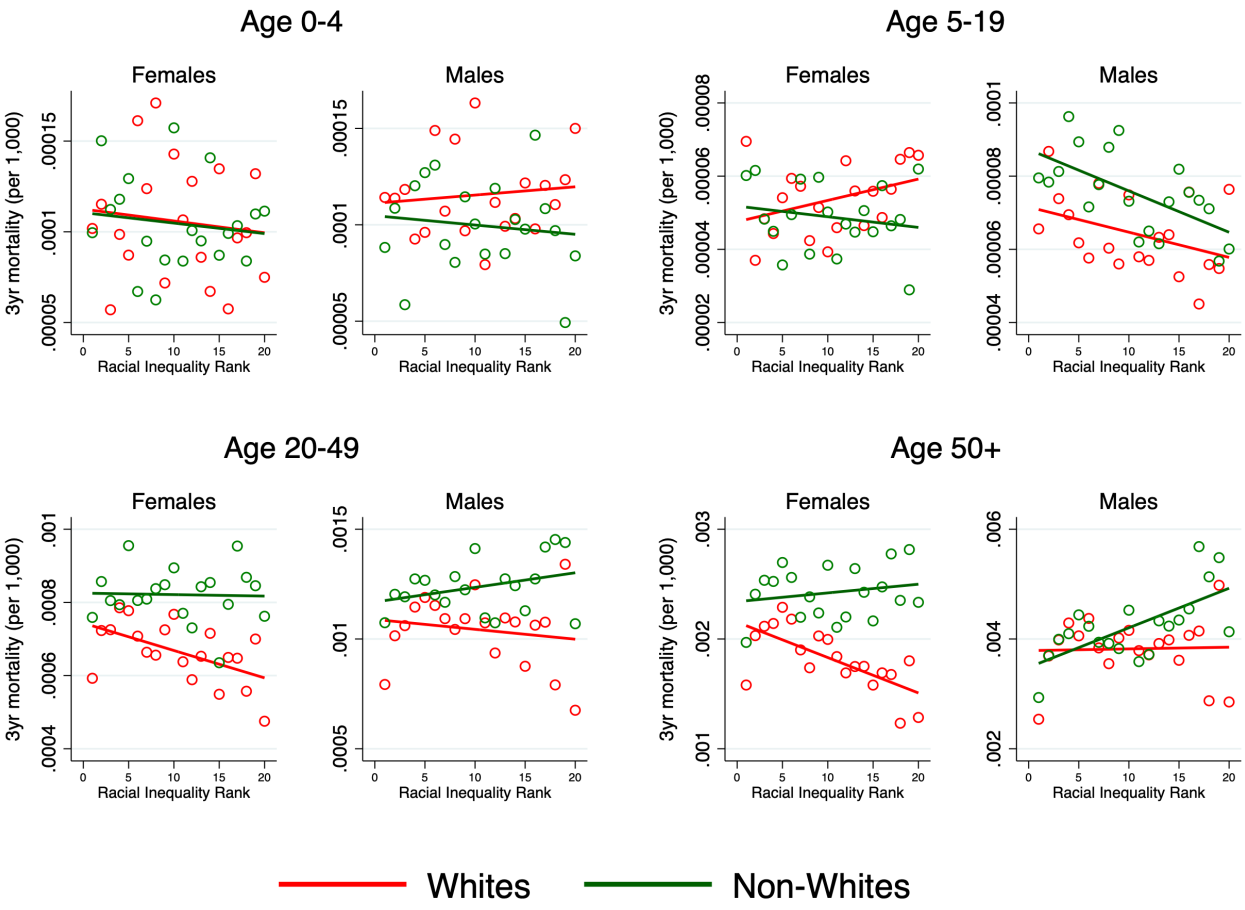
Note: Three-year death rates by racial income gap ventiles across age for females and males. Average 3-year death rates are plotted across groups of Brazilian municipalities. Each bin represents a group of municipalities with about 5% of the overall population in 2010. Straight lines provide linear fits.

Figure 5: Infectious diseases mortality and racial income gap



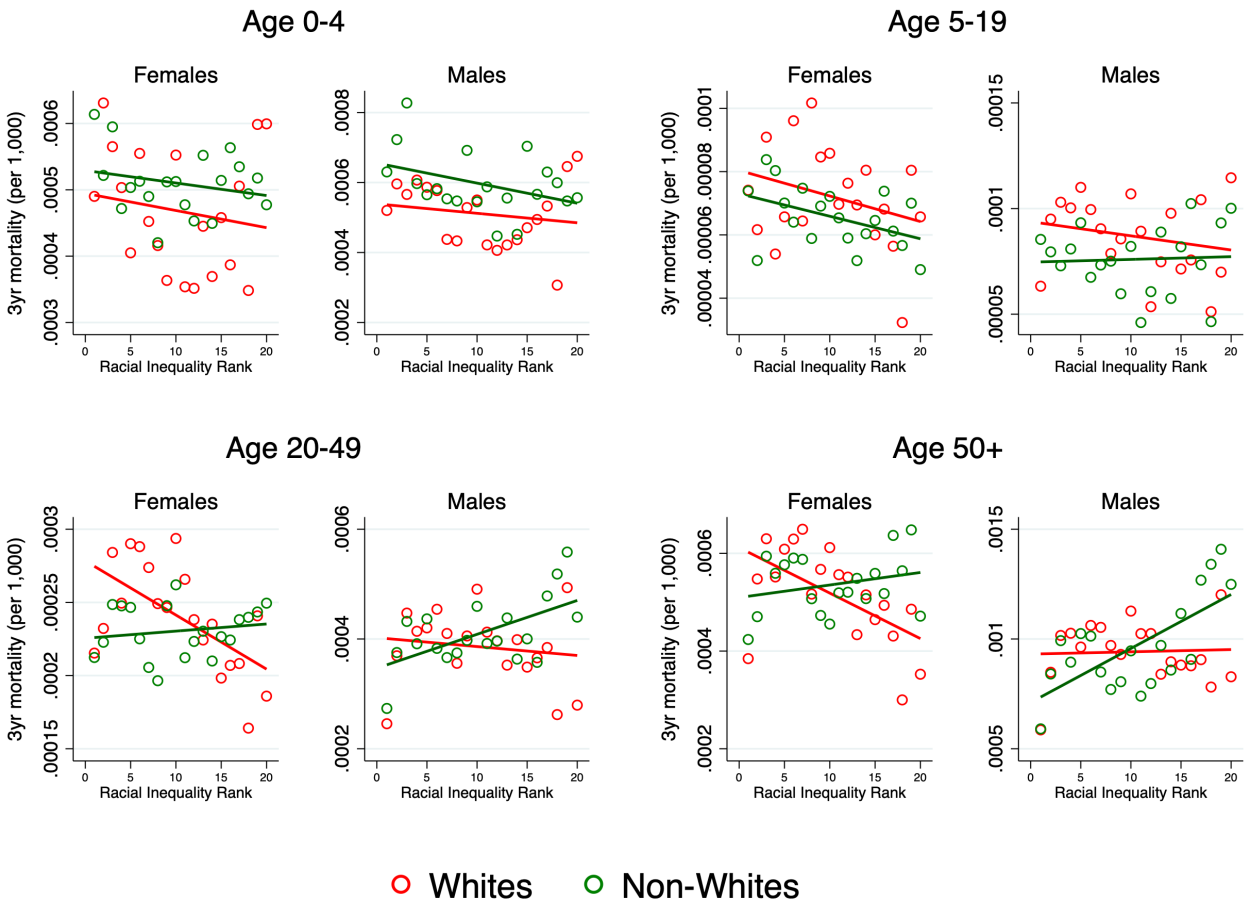
Note: Three-year death rates by racial income gap ventiles across age for females and males. Average 3-year death rates are plotted across groups of Brazilian municipalities. Each bin represents a group of municipalities with about 5% of the overall population in 2010. Straight lines provide linear fits.

Figure 6: Cardiovascular diseases mortality and racial income gap



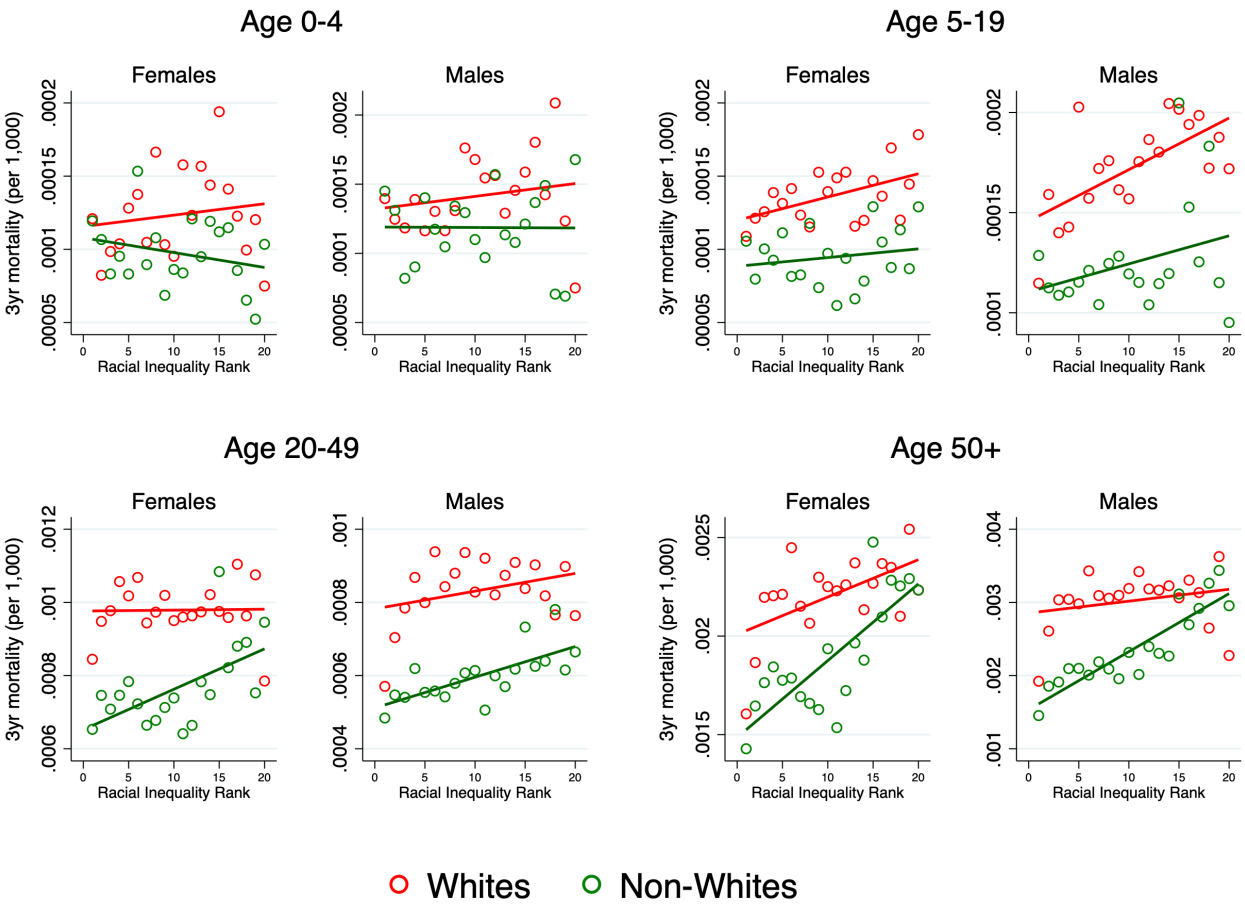
Note: Three-year death rates by racial income gap ventiles across age for females and males. Average 3-year death rates are plotted across groups of Brazilian municipalities. Each bin represents a group of municipalities with about 5% of the overall population in 2010. Straight lines provide linear fits.

Figure 7: Respiratory diseases mortality and racial income gap



Note: Three-year death rates by racial income gap ventiles across age for females and males. Average 3-year death rates are plotted across groups of Brazilian municipalities. Each bin represents a group of municipalities with about 5% of the overall population in 2010. Straight lines provide linear fits.

Figure 8: Cancer mortality and racial income gap



Note: Three-year death rates by racial income gap ventiles across age for females and males. Average 3-year death rates are plotted across groups of Brazilian municipalities. Each bin represents a group of municipalities with about 5% of the overall population in 2010. Straight lines provide linear fits.

9 Tables

Table 1: Descriptive average statistics across municipalities in Brazil, 2010 (N=5,565).

Variable	All Municipalities		Whites		Non-Whites	
	Mean	SD	Mean	SD	Mean	SD
Age	37.47	1.75	37.89	1.83	37.05	1.57
Males	0.51	0.03	0.50	0.03	0.52	0.03
Employed rate	0.65	0.10	0.66	0.10	0.64	0.10
High School Dropout	0.54	0.18	0.51	0.18	0.56	0.18
Poverty (1/4 MW)	0.23	0.17	0.20	0.15	0.24	0.17
Share Urban	0.65	0.22	0.66	0.22	0.64	0.23
Share Young (18 to 30 years old)	0.36	0.06	0.35	0.06	0.38	0.05
Years of Schooling	6.33	1.26	6.93	1.22	5.72	0.97
Household Size	4.00	0.54	3.87	0.51	4.12	0.54
Monthly Income (2010 R$)	872.8	366.2	1,025.9	418.4	719.7	215.2
Racial Income Gap (2010 R$)	306.16	305.30				
Share Whites	0.47	0.24				
Population	34,046	201,560				
Gini Index	0.50	0.07				
Gov. Spending per capita	1,284.7	746.2				
Gov. Revenue per capita	1,941.3	1,132.8				

Note: This table shows data on 5,565 Brazilian municipalities. High school dropouts correspond to the share of 14–18-year-old children who are not in school. The racial income gap is the difference in the average monthly earnings between Whites and Non-Whites. The source of all variables is the 2010 Brazilian Census, except for annual government spending and government revenue at the municipality level which we obtain from the Ministry of Finance (Ministério da Fazenda – Secretaria do Tesouro Nacional).

Table 2: Analysis of race-based income inequality and mortality.

	Males			**Females**		
Panel A- Ages 0 to 4	(1)	(2)	(3)	(1)	(2)	(3)
Non-Whites × *ln(Dif)*	0.001	0.277**	0.152*	0.199**	0.477***	0.335***
	(0.084)	(0.091)	(0.080)	(0.092)	(0.099)	(0.089)
Observations	7,634	7,634	7,634	6,978	6,978	6,978
R^2	0.201	0.257	0.171	0.228	0.288	0.191
Fstat	55.937	22.388	11.362	63.757	39.492	24.607
Panel B- Ages 5 to 19						
Non-Whites × *ln(Dif)*	0.257**	0.643***	0.558***	0.098	0.328***	0.306***
	(0.122)	(0.127)	(0.123)	(0.089)	(0.097)	(0.092)
Observations	6,931	6,931	6,931	5,283	5,283	5,283
R^2	0.118	0.187	0.199	0.248	0.304	0.230
Fstat	4.978	9.259	8.754	73.697	33.052	26.620
Panel C- Ages 20 to 49						
Non-Whites × *ln(Dif)*	0.017	0.565***	0.498***	0.209**	0.610***	0.491***
	(0.090)	(0.090)	(0.086)	(0.065)	(0.070)	(0.063)
Observations	10,287	10,287	10,287	9,353	9,353	9,353
R^2	0.117	0.225	0.200	0.197	0.292	0.294
Fstat	0.735	56.871	46.310	77.032	32.631	29.699
Panel D- Ages 50 and more						
Non-Whites × *ln(Dif)*	-0.207***	0.284***	0.135**	-0.187***	0.252***	0.085
	(0.060)	(0.068)	(0.059)	(0.056)	(0.065)	(0.057)
Observations	10,882	10,882	10,882	10,779	10,779	10,779
R^2	0.325	0.388	0.391	0.416	0.465	0.483
Fstat	238.554	27.221	36.333	461.579	81.674	99.936
Controls	**No**	**Yes**	**Yes**	**No**	**Yes**	**Yes**

Clustered standard errors in parentheses

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

Note: Municipality level data. Columns 1 and 2 show regressions that are weighted by the total population in the municipality. Standard errors are clustered at the municipality level. Regressions in column 3 are weighted by the racial group population in the municipality.

Table 3: Between-race analysis of race-based income inequality and mortality (Group Level)

	Males			**Females**		
Panel A- Ages 20 to 34	(1)	(2)	(3)	(1)	(2)	(3)
Non-Whites × *ln(Dif)*	0.350***	0.622***	0.587***	0.246***	0.276***	0.242***
	(0.097)	(0.096)	(0.094)	(0.064)	(0.063)	(0.058)
Observations	9,186	9,186	9,186	7,052	7,052	7,052
R^2	0.196	0.240	0.280	0.110	0.141	0.135
Fstat	56.707	95.524	85.001	5.575	7.343	8.974
Panel B- Ages 35 to 44						
Non-Whites × *ln(Dif)*	0.086	0.190***	0.196***	0.147***	0.157***	0.162***
	(0.055)	(0.053)	(0.052)	(0.044)	(0.046)	(0.041)
Observations	9,064	9,064	9,064	7,456	7,456	7,456
R^2	0.162	0.178	0.163	0.111	0.132	0.122
Fstat	65.471	69.670	78.406	12.638	7.388	12.242
Panel C- Ages 45 to 54						
Non-Whites × *ln(Dif)*	-0.021	0.071*	0.073**	0.030	0.040	0.063**
	(-0.58)	(1.92)	(2.16)	(0.84)	(1.12)	(2.16)
Observations	9,652	9,652	9,652	8,551	8,551	8,551
R^2	0.177	0.199	0.180	0.113	0.145	0.153
Fstat	24.868	42.934	44.244	7.794	6.306	10.280
Panel D- Ages 55 to 64						
Non-Whites × *ln(Dif)*	-0.085***	-0.006	0.019	-0.018	0.010	0.011
	(0.023)	(0.023)	(0.021)	(0.021)	(0.022)	(0.019)
Observations	10,384	10,384	10,384	9,456	9,456	9,456
R^2	0.242	0.276	0.274	0.148	0.183	0.195
Fstat	4.668	21.491	16.467	3.386	2.088	1.481
Controls	**No**	**Yes**	**Yes**	**No**	**Yes**	**Yes**

Clustered standard errors in parentheses

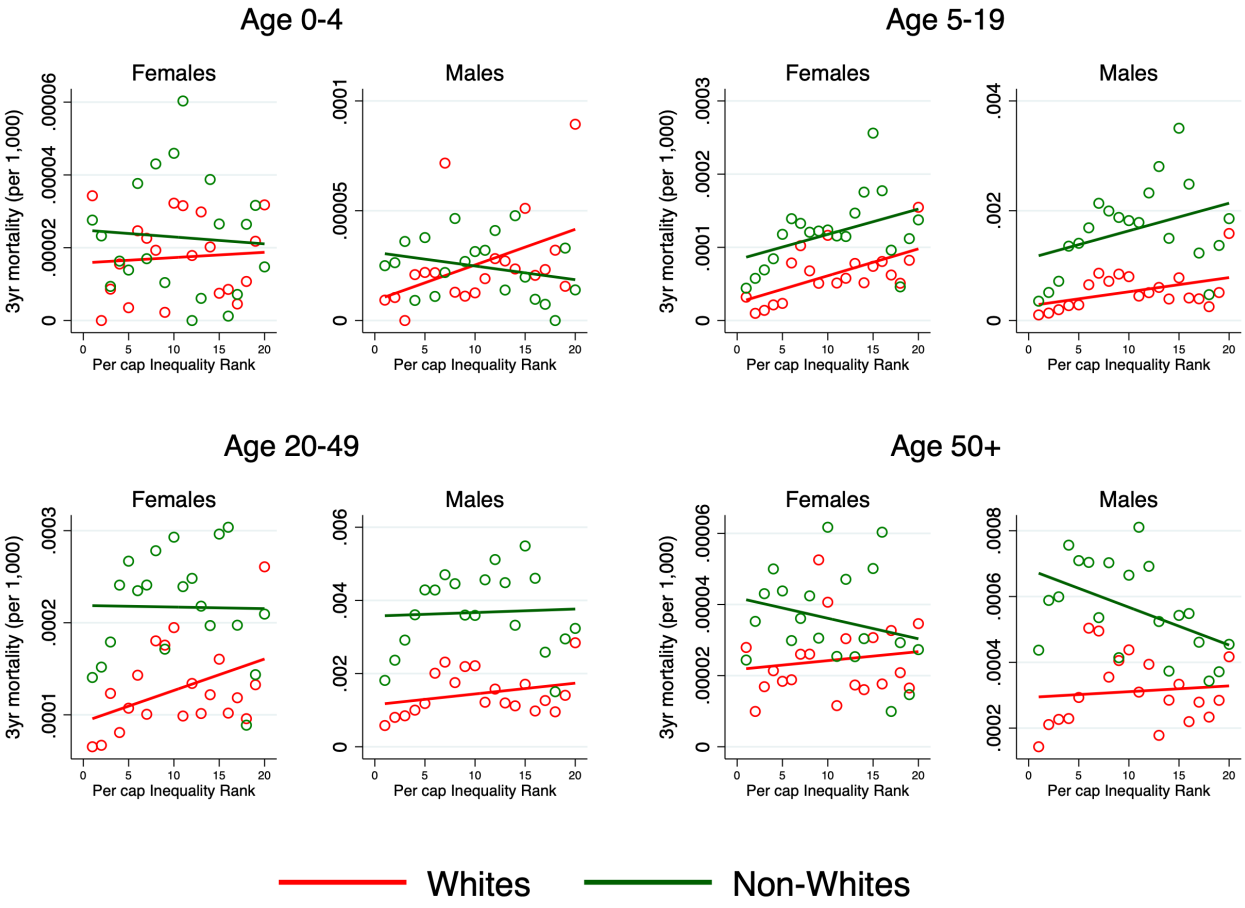
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Note: Group levels are defined by gender, age, and race by municipality. We average across all individuals within each municipality and group. Columns 1 and 2 show regressions that are weighted by the total population in the municipality. Standard errors are clustered at the municipality level. Regressions in column 3 are weighted by the racial group population in the municipality.

10 Appendix

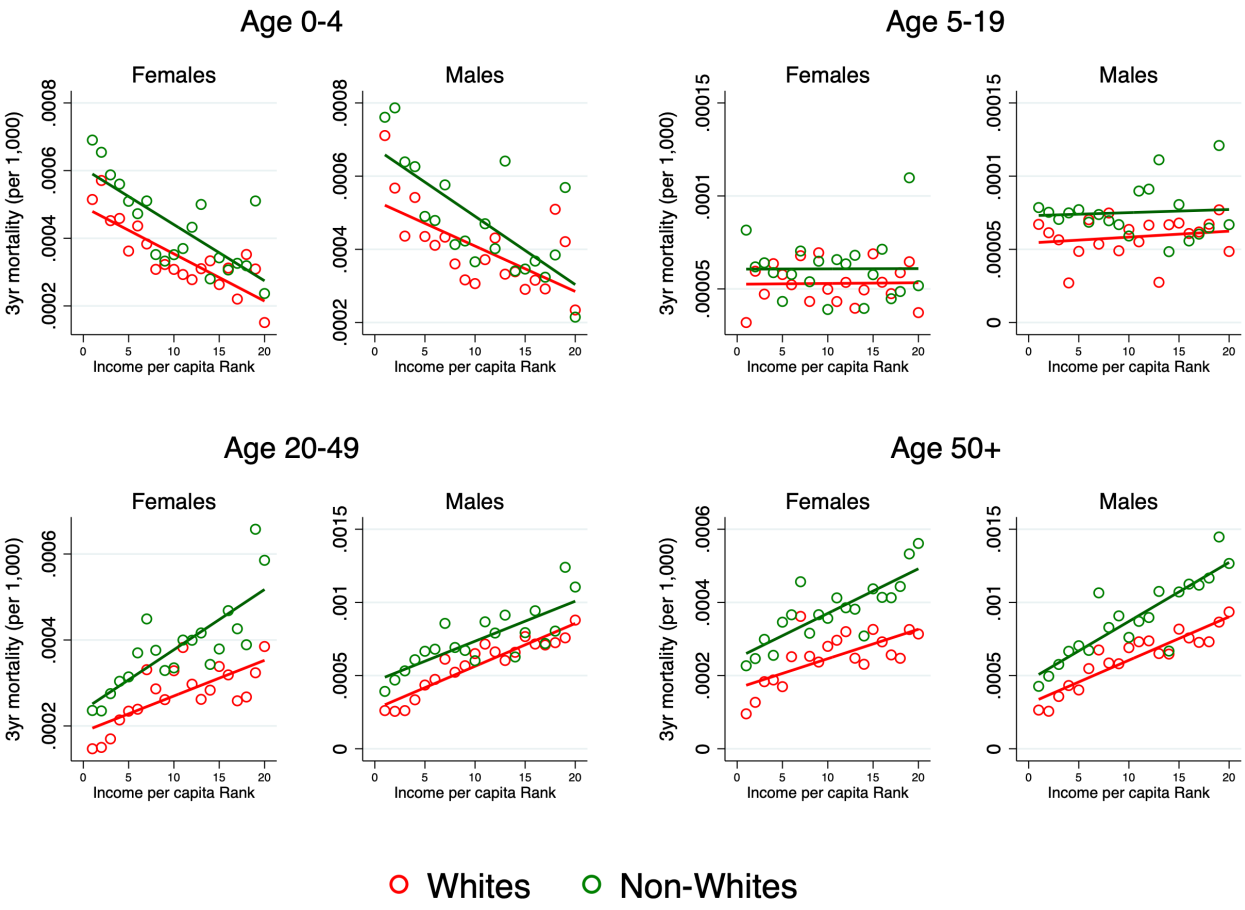
Figures

Figure A1: Homicides and per capita income



Note: Three-year death rates by per capita income ventiles across age for females and males. Average 3-year death rates are plotted across groups of Brazilian municipalities. Each bin represents a group of municipalities with about 5% of the overall population in 2010. Straight lines provide linear fits.

Figure A2: Infectious diseases and per capita income



Note: Three-year death rates by per capita income ventiles across age for females and males. Average 3-year death rates are plotted across groups of Brazilian municipalities. Each bin represents a group of municipalities with about 5% of the overall population in 2010. Straight lines provide linear fits.

Tables

Table A1: Between-race analysis of Race-based Income Inequality and Mortality (Micro-region level)

	Males			**Females**		
Panel A- Ages 0 to 4	(1)	(2)	(3)	(1)	(2)	(3)
Non-Whites × *ln(Dif)*	-0.494	0.384	0.125	-0.355	0.437	0.277
	(0.145)	(0.269)	(0.669)	(0.291)	(0.197)	(0.351)
Observations	818	818	818	813	813	813
R^2	0.288	0.381	0.309	0.315	0.396	0.336
Fstat	3.870	12.568	7.814	4.598	9.501	6.477
Panel B- Ages 5 to 19						
Non-Whites × *ln(Dif)*	-0.192	0.694**	0.625*	-0.157	0.658**	0.456*
	(0.345)	(0.350)	(0.321)	(0.262)	(0.291)	(0.254)
Observations	815	815	815	785	785	785
R^2	0.341	0.388	0.431	0.244	0.329	0.253
Fstat	7.280	34.121	32.616	7.840	13.071	9.449
Panel C- Ages 20 to 49						
Non-Whites × *ln(Dif)*	-0.418	0.572*	0.429	-0.141	0.501**	0.334*
	(-1.29)	(1.85)	(1.54)	(-0.64)	(2.33)	(1.84)
Observations	826	826	826	823	823	823
R^2	0.341	0.446	0.409	0.318	0.395	0.370
Fstat	14.622	69.700	52.140	4.195	35.027	26.105
Panel D- Ages 50 and more						
Non-Whites × *ln(Dif)*	-0.808***	-0.132	-0.308**	-0.693***	-0.113	-0.243**
	(0.178)	(0.163)	(0.135)	(0.136)	(0.119)	(0.104)
Observations	826	826	826	825	825	825
R^2	0.367	0.512	0.493	0.488	0.589	0.582
Fstat	19.011	17.724	11.830	58.668	6.515	3.811
Controls	**No**	**Yes**	**Yes**	**No**	**Yes**	**Yes**

Clustered standard errors in parentheses

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

Note: We aggregated the data into 413 micro-regions. Columns 1 and 2 show regressions that are weighted by the total population in the micro-region. Standard errors are clustered at the micro-region level. Regressions in column 3 are weighted by the racial group's population in the micro-region.

Table A2: Robustness Checks (Distributing deaths with missing information on race)

	Males			**Females**		
Panel A- Ages 0 to 4	(1)	(2)	(3)	(1)	(2)	(3)
Non-Whites × *ln(Dif)*	0.207**	0.314***	0.402***	0.384***	0.454***	0.609***
	(0.005)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	7,901	2,962	7,901	7,302	2,862	7,302
R^2	0.130	0.159	0.220	0.145	0.171	0.244
Fstat	3.810	6.137	15.671	9.860	8.761	33.986
Panel B- Ages 5 to 19						
Non-Whites × *ln(Dif)*	0.521***	0.512***	0.604***	0.259**	0.257**	0.374***
	(0.000)	(0.000)	(0.000)	(0.004)	(0.005)	(0.000)
Observations	7,098	5,621	7,098	5,439	4,574	5,439
R^2	0.206	0.221	0.237	0.185	0.169	0.328
Fstat	13.491	16.766	6.559	13.292	9.102	32.313
Panel C- Ages 20 to 49						
Non-Whites × *ln(Dif)*	0.376***	0.368***	0.476***	0.408***	0.396***	0.559***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	10,351	8,157	10,351	9,477	7,746	9,477
R^2	0.221	0.233	0.266	0.247	0.253	0.380
Fstat	81.945	79.313	29.690	22.130	22.526	32.815
Panel D- Ages 50 and more						
Non-Whites × *ln(Dif)*	0.099	0.098	0.082	0.078	0.049	0.087
	(0.103)	(0.161)	(0.295)	(0.156)	(0.433)	(0.245)
Observations	10,928	5,602	10,928	10,853	5,621	10,853
R^2	0.293	0.334	0.381	0.365	0.408	0.447
Fstat	9.083	8.034	15.476	21.912	20.753	57.079
Controls	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Clustered standard errors in parentheses

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

Note: All regressions are weighted by the racial group population in the municipality. Columns 1 and 2 show regressions where all deaths with missing information on race are assumed to be from Non-Whites individuals. In column 2 we excluded cases with a population less than 500. Column 3 shows regressions in which 38% of deaths with missing information on race are distributed to whites and 68% are distributed to Non-Whites. Standard errors are clustered at the municipality level.

10.1 Coverage of death registries

The lower coverage of death registries in the North and Northeast regions of Brazil could raise the suspicion that our results are driven by underreported deaths in these areas. We present estimations in which we exclude the north and northeast regions. We now have a sample composed of 2,684 municipalities from the south, southeast and center-west regions (nearly 50% of Brazilian municipalities). These death records display a coverage of 99% which is comparable to the death registries of developed countries. The racial composition, however, is fairly different. **Table A3** displays our results. We see that our main results concerning the 20-49 age group are identical to previous estimations and indicate that a 1% increase in the racial income gap is associated with 0.5-0.6% in Non-White mortality in Brazilian municipalities.

Table A3: Estimations excluding north and northeast regions

	Males			**Females**		
Panel A- Ages 0 to 4	(1)	(2)	(3)	(1)	(2)	(3)
Non-Whites × *ln(Dif)*	0.383**	0.503***	0.427***	0.572***	0.697***	0.583***
	(0.003)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Observations	3,986	3,986	3,986	3,607	3,607	3,607
R^2	0.372	0.398	0.329	0.402	0.427	0.351
Fstat	103.883	47.184	49.423	90.718	56.773	53.249
Panel B- Ages 5 to 19						
Non-Whites × *ln(Dif)*	0.632***	0.784***	0.650***	0.394**	0.475***	0.447***
	(0.122)	(0.129)	(0.122)	(0.124)	(0.138)	(0.125)
Observations	3,892	3,892	3,892	2,773	2,773	2,773
R^2	0.300	0.318	0.269	0.407	0.431	0.372
Fstat	63.546	32.732	27.953	118.577	39.869	47.662
Panel C- Ages 20 to 49						
Non-Whites × *ln(Dif)*	0.694***	0.944***	0.763***	0.543***	0.749***	0.617***
	(6.71)	(8.64)	(7.65)	(5.72)	(7.55)	(7.22)
Observations	6,070	6,070	6,070	5,426	5,426	5,426
R^2	0.293	0.333	0.272	0.371	0.410	0.362
Fstat	92.679	43.524	37.732	179.380	60.274	66.587
Panel D- Ages 50 and more						
Non-Whites × *ln(Dif)*	0.266**	0.562***	0.422***	0.248**	0.472***	0.345***
	(0.085)	(0.100)	(0.092)	(0.088)	(0.100)	(0.093)
Observations	6,383	6,383	6,383	6,289	6,289	6,289
R^2	0.549	0.568	0.557	0.596	0.610	0.609
Fstat	497.298	121.869	116.770	637.795	171.431	167.485
Controls	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Clustered standard errors in parentheses

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

Note: Municipality level data. Columns 1 and 2 show regressions that are weighted by the total population in the municipality. Standard errors are clustered at the municipality level. Regressions in column 3 are weighted by the racial group population in the municipality.

Table A4: Robustness check II - Placebo with per capita income

	Males			**Females**		
Panel A- Ages 0 to 4	(1)	(2)	(3)	(1)	(2)	(3)
Non-Whites × *ln(Dif)*	-0.267***	-0.208***	-0.141**	-0.197**	-0.133*	-0.058
	(0.000)	(0.000)	(0.004)	(0.003)	(0.056)	(0.308)
Observations	7,634	7,634	7,634	6,978	6,978	6,978
R^2	0.237	0.261	0.198	0.261	0.282	0.214
Fstat	54.157	19.631	18.666	74.984	30.496	30.341
Panel B- Ages 5 to 19						
Non-Whites × *ln(Dif)*	-0.129**	-0.050	0.008	-0.099*	-0.032	0.032
	(0.057)	(0.061)	(0.059)	(0.054)	(0.059)	(0.051)
Observations	6,931	6,931	6,931	5,283	5,283	5,283
R^2	0.149	0.178	0.193	0.257	0.299	0.235
Fstat	1.901	3.190	7.095	86.534	26.881	28.049
Panel C- Ages 20 to 49						
Non-Whites × *ln(Dif)*	-0.406***	-0.295***	-0.233***	-0.183***	-0.076**	-0.036
	(-8.83)	(-6.20)	(-5.00)	(-5.19)	(-2.01)	(-1.05)
Observations	10,287	10,287	10,287	9,353	9,353	9,353
R^2	0.195	0.238	0.214	0.236	0.281	0.283
Fstat	63.549	61.544	70.851	51.432	12.017	23.393
Panel D- Ages 50 and more						
Non-Whites × *ln(Dif)*	-0.430***	-0.328***	-0.256***	-0.382***	-0.278***	-0.208***
	(0.029)	(0.034)	(0.032)	(0.029)	(0.033)	(0.030)
Observations	10,882	10,882	10,882	10,779	10,779	10,779
R^2	0.393	0.410	0.398	0.463	0.477	0.470
Fstat	224.098	35.828	28.326	462.696	59.596	59.430
Controls	**No**	**Yes**	**Yes**	**No**	**Yes**	**Yes**

Clustered standard errors in parentheses

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

Note: Municipality level data. Columns 1 and 2 show regressions that are weighted by the total population in the municipality. Standard errors are clustered at the municipality level. Regressions in column 3 are weighted by the racial group population in the municipality.