Adult Mortality Differentials and Regional Development at the local level in Brazil.

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Abstract

Brazil's profound regional social inequality raises questions regarding its impact on adult mortality and data quality. While the quality of mortality data has improved in recent decades, significant regional disparities persist in death registration completeness and mortality levels. This study examines the spatial and temporal trends of adult mortality in Brazil's small regions from 1980 to 2010. We analyze their connections with socioeconomic and public health advancements, assessing whether adult mortality rates exhibit convergence or divergence. Utilizing mortality data and census information, we employ spatial autoregressive models to explore the relationship between adult mortality, socioeconomic factors, and public health measures across 558 microregions. Our findings highlight social inequality as a key determinant of regional disparities in adult mortality. Male adult mortality demonstrates sensitivity to unemployment and wealth inequality, exhibiting a considerable increase towards the inland areas of Brazil, likely attributable to rising violence and homicides associated with organized crime. Socioeconomic disparities emerge as the primary drivers of variation in adult mortality within the country, with the potential to become the leading explanation for differences in life expectancy.

Keywords: Adult Mortality, Small Areas, Brazil

Introduction

Brazil has experienced a substantial decline in mortality rates across multiple population groups—including infants, children, and adults—which has contributed to an increase in life expectancy at birth of approximately 25 years between 1950 and 2020 (Szwarcwald et al. 2020; Barufi, Haddad, and Paez 2012; Sousa, Hill, and Dal Poz 2010; Queiroz et al. 2020). The rate of this improvement in life expectancy has exceeded that observed in several developed countries (Palloni and Pinto-Aguirre 2011; França et al. 2017; Alvarez, Aburto, and Canudas-Romo 2020).

During the same period, Brazil has also experienced a long-term trend toward convergence in infant mortality rates, largely facilitated by a decrease in the incidence of infectious diseases (Barufi, Haddad, and Paez 2012). Despite these improvements, pronounced regional inequalities in adult mortality remain evident (Szwarcwald et al. 2020; Borges 2017; Schmertmann and Gonzaga 2018; Queiroz et al. 2020). These persistent disparities are primarily driven by entrenched socioeconomic and income-related inequalities (Fenelon 2013; Couillard et al. 2021; Ezzati et al. 2008; Rau and Schmertmann 2020).

Recent shifts in life expectancy increasingly reflect differences in adult mortality, underscoring the urgent need to address these inequalities and to generate more precise local-level mortality estimates. Although Brazil has made important strides in enhancing the coverage and reliability of death registration in recent years, significant heterogeneity in data completeness continues to characterize different regions of the country (Diogenes et al. 2022; Queiroz et al. 2020b; Adair and Lopez 2018; Queiroz et al. 2017; Paes 2005). These inconsistencies pose challenges to producing comprehensive analyses of adult mortality patterns and their underlying determinants across the national territory (Diogenes et al. 2022; Bilal et al. 2019; Queiroz et al. 2020; Baptista and Queiroz 2019a, 2019b).

In light of the growing interest in understanding adult mortality dynamics at smaller geographic scales, it becomes imperative to adopt alternative methodological strategies capable of producing reliable local estimates. Analyses that neglect variations in data quality over time and space risk producing misleading conclusions and may compromise evidence-based policy formulation.

In this context, our study examines adult mortality patterns across 558 comparable microregions of Brazil from 1980 to 2010. It analyzes spatial and temporal trends in adult mortality in these small areas, exploring their association with socioeconomic development and public health improvements. Additionally, the study investigates mortality variations over time and space, with particular attention to differences by gender and across regions.

Data and Methods

Data

We use data from four population censuses conducted in Brazil during the years 1980, 1991, 2000, and 2010 and Mortality Information from the Ministry of Health Mortality Information System (MIS. SIM in Portuguese). We aggregated municipalities into comparable small areas, aligning with the microregion delineation as defined by the Brazilian Institute of Geography and Statistics (IBGE in Portuguese). This approach allows us to track and analyze adult mortality in 558 distinct small areas in Brazil from 1980 to 2010. Other socioeconomic and health indicators, used to explain mortality regional differentials, are also collected from population censuses and Ministry of Health data. In next Box 1 we present the set of explanatory variables and our dependent variable.

Methods of Analysis

Our main variable of interest is adult mortality rates measured by the intercensal probability of dying from ages 15 to 60, ${}_{45}q_{15}$. We use mortality estimates from previous studies that followed the methodology outlined in Queiroz et al. (2020) and Lima et al. (2024). The method proposes a combination of Death Distribution Methods (DDM) with Topals regression model to smooth mortality across single-age groups (Gonzaga and Schmertmann, 2016; De Beer, 2012).

We estimate regression models for variations in adult mortality, spanning the intercensal periods 1991-2000 and 2000-2010. The analytical framework employs simultaneous auto-regression models (SAR) to scrutinize the relationships between explanatory variables (socioeconomic and health variables) and our dependent variable. We argue that adult mortality in Brazil exhibits spatial clustering, necessitating the incorporation of spatial considerations into the analysis (Roux, 2007; Anselin and

Arribas-Bel, 2013). Consequently, we presume that the observed dependent variable in one microregion is influenced by the values of the dependent variable in its neighboring locations.

BOX 1: List of explanatory and response variables

Variable	Description	Expected Sign
45q15	Intercensal probability of death from age 15 to 60. For the censuses periods of 1991 2000 and 2010.	Response variable
Schooling	Percentage of residents with 8 and more years of schooling in 1991, 2000 and 2010.	Inverse relation to mortality levels. More education, lower mortality
Illiteracy rate	Percentage of illiterates in the population in 1991, 2000 and 2010.	Positive relation. higher illiteracy rates, higher mortality levels.
Poverty rate	Percentage of individuals with less than ¼ minimum wage income in 1991, 2000 and 2010.	Positive relation, higher poverty rates, higher mortality levels.
Per capita household income	Household income level in 1991, 2000 and 2010.	Negative (inverse) relation.
Gini	Gini index as a measure of income distribution and relative poverty.	Positive relation, higher inequality higher mortality.
Youth Population	Ratio of individuals aged 20 to 39 in each local area in 1991, 2000 and 2010.	Positive relation. Higher external rates of mortality.
Population size (degree of urbanization)	The population size of each microregion in 1991, 2000 and 2010, as sort of urbanization degree.	Concentration might be positive related to mortality levels.
Unemployment rate	Percentage of people without a job and looking for a job in the reference week in 1991, 2000 and 2010.	Positive relation. Higher unemployment related to higher mortality.
Longitude and Latitude coordinates	Spatial control variables.	Spatial variables that capture effects of mortality geographical trends (spatial large-scale variation).
Regional control variables	Dummies for regions and local areas.	Capture effects of unobserved variables.
Spatial term	Type of spatial dependency	Spatial autocorrelation or heterogeneity control that captures clusters of similar observations or geographical differences in mortality (small scale variation)

The analysis employs two spatially dependent specifications: spatial lagged and spatial correlated errors. The former posits that the values of the dependent variable in one geographic unit *i* are directly impacted by the values of the dependent variable found in the neighboring units (*i's* neighbors). This influence is considered over and above other covariates that pertain specifically to unit *i*. In cases where the dependent variable's values are not directly influenced by the values of its neighbors but instead exhibit some form of spatial clustering (not explicitly defined in the model), a spatial correlated error model is fitted (Ward and Gleditsch, 2007). If spatial dependence is observed in both specifications, the most appropriate model is a Spatial Auto-Regressive model with an additional Auto-Regressive error structure (SARAR).

It is important to note that the models are estimated solely for the period from 1991 to 2010 due to the unavailability of numerous explanatory variables for the year 1980, which constitutes a limitation of this study. However, this limitation does not compromise our analysis, as the country has experienced a notable increase in external causes of death since the 1990s, consequently leading to higher young adult mortality (Mendes et al. 2015).

Model selections

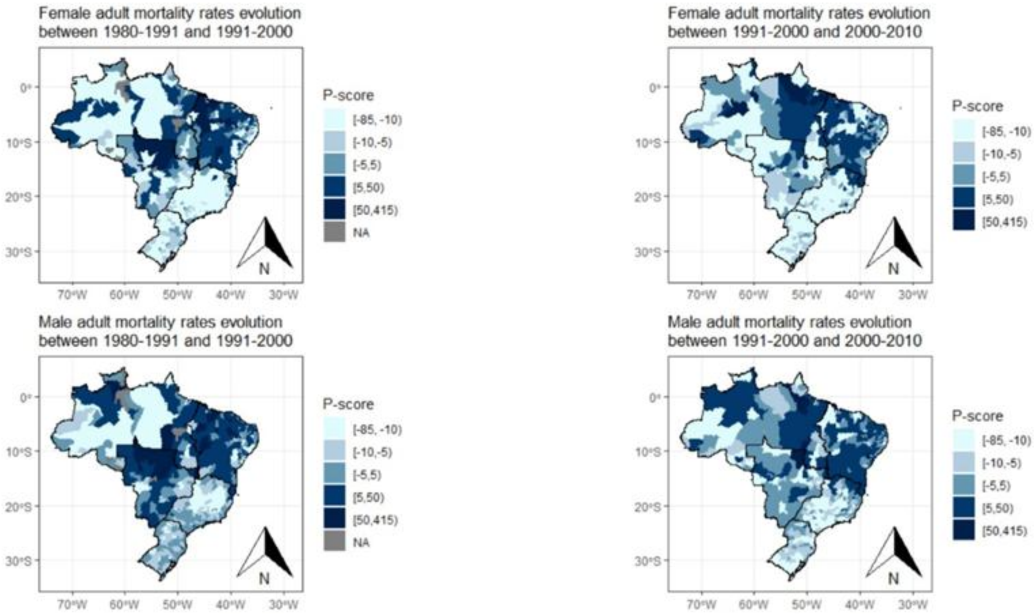
The construction of the models follows a cascade format. Initially, variable selection was conducted through the construction of correlation matrices, from which variables with the lowest pairwise correlation values were selected. Subsequently, multicollinearity tests were applied using Variance Inflation Factors (VIFs) to refine the final set of variables. The next steps involved model construction, which also proceeded in stages. The first stage comprised: (1) the application of linear models, along with tests for homoscedasticity using the Breusch–Pagan test; (2) subsequently, we applied Rao's score test (also known as the Lagrange Multiplier test) to diagnose spatial dependence in linear models. Once spatial dependence was specified, both the linear and spatial models were evaluated using the likelihood ratio test to identify the most appropriate model specification; and (3) finally, we conducted a Breusch–Pagan test for heteroskedasticity on the least squares estimation of the spatial models, taking into account the spatial coefficients rho (spatial lagged dependency) or lambda (spatial error model). In cases where heteroskedasticity was detected, whether in the spatial or linear models, corrective models were applied. In the cases that we identify heteroskedasticity in the spatial models, we fit a Cliff-Ord-type model with heteroskedastic correction (Arraiz et al. 2008).

Results

Figure 1 illustrates changes in adult mortality, measured by ${}_{45}q_{15}$, across two time periods. The values represent p-scores or ratios of ${}_{45}q_{15}$, i.e. *P-Score* = P(t+1) – P(t)/ P(t). Strongly negative values (depicted in light blue) indicate improvements in adult mortality, signifying an adult mortality decline between ages 15 and 60 through periods. Conversely, positive values (shown in dark blue) reflect a deterioration in adult mortality, with higher mortality rates in the latter period.

Overall, from 1980 to 2010, Figure 1 reveals a general decline in adult mortality rates across most regions of Brazil for both men and women. Nevertheless, some poorest areas in the central and northern regions exhibit increased adult mortality across both time intervals, especially in most recent periods. Although the number of such areas is smaller when comparing to the intercensal periods of 1991–2000 and 2000–2010, the spatial distribution of worsening mortality remains consistent with the earlier period.

Figure 1: Adult mortality rates in microregions of Brazil from 1980 until 2010



Sources: Ministry of Health; Population censuses, IBGE.

Figure 1 further indicates evidence of adult mortality improvements, particularly among women, when comparing the maps for the 2000–2010 period with those from 1991–2000, and especially with the earlier period of 1980–1991, which exhibits a higher concentration of dark blue areas. As of the current time, the majority of the 2022 Brazilian Demographic Census results remain unpublished. Upon their release, these data may facilitate an assessment of whether socioeconomic conditions in the more adversely affected regions of the central-northern strip have improved, and if such improvements correlate with reductions in adult mortality.

The table 1 presents the results of the explanatory model with a spatial component for adult mortality rates variations. The statistically significant spatial error term, observed for both sexes, may indicate the presence of spatially correlated unobservable latent variables not accounted for within the models. This phenomenon may also arise from area boundaries that inadequately delineate the true neighborhoods from which the analyzed variables are derived. Spatial autocorrelation attributable to these factors is generally regarded as a nuisance.

For women, two explanatory variables—change in average population size and change in average years of schooling—emerge as significant, both with negative coefficients. This suggests that increases in average years of schooling and degree of urbanization within a microregion are associated with reductions in adult mortality.

Regarding the model for men, the statistical significant explanatory variables include changes in average unemployment rates, average population size, and average years of schooling. The estimated coefficients indicate that a decrease in average unemployment rates is associated with a reduction in adult mortality. Additionally, similar to the findings for women, increases in both population size and average years of schooling are also associated with declines in adult mortality for men.

It is also crucial to emphasize the spatial trend dimension of the model for men. The statistically significant coefficient for longitude suggests a discernible spatial pattern. As depicted in the maps presented in Figure 1, particularly the map illustrating the change in male mortality between the 1991–2000 and 2000–2010 periods, there appears to be a slight increase in areas exhibiting higher mortality (represented by darker shading in Figure 1) with westward progression—especially within the northern and northeastern regions of the country. This spatial pattern is further corroborated by the positive and significant coefficient for longitude, indicating that higher longitude values, corresponding to locations situated further west of the Greenwich meridian, are associated with elevated adult mortality rates. Additionally, these findings offer potential explanations for the darker areas depicted in Figure 1, suggesting that social and economic advancements in these microregions may contribute to reductions in adult mortality within the central-northern region of Brazil.

Table 1: Spatial Models Explaining Variations in Adult Mortality Rates by Sex, Microregions, Brazil (1991-2000 and 2000-2010).

Spatial error models for variations in adult mortality rates*							
Models to explain variations in female adult mortality between periods				Models to explain variations in male adult mortality between periods			
Variables varied across time	Estimate	Pr(>|t|)	Sig.	Variables varied across time	Estimate	Pr(>|t|)	Sig.
Intercept	0.0445	0.031	*	Intercept	0.1174	0.000	***
Variation of average unemployment rates	0.0020	0.200		Variation of average unemployment rates	0.0047	0.006	**
Variation of average gini index	0.0201	0.629		Variation of average gini index	-0.0802	0.176	
Variation of average per capita income	-0.00003	0.125		Variation of average per capita income	-0.00003	0.222	
Variation of average hospital costs	0.0000	0.401		Variation of average hospital costs	0.0000	0.061	.
Variation of average population size in 10^6	-0.0143	0.032	*	Variation of average population size in 10^6	-0.0338	0.002	**
Variation of female average years of schooling	-0.0023	0.000	***	Variation of male average years of schooling	-0.0031	0.000	***
Variation of female average youth population	0.3670	0.074	.	Variation of male average youth population	0.1615	0.582	
Region North ref.				Region North ref.			
Region Northeast	-0.0091	0.258		Region Northeast	-0.0292	0.004	**
Region Southeast	-0.0099	0.254		Region Southeast	-0.0357	0.001	***
Region South	-0.0031	0.759		Region South	-0.0181	0.122	
Region Midwest	-0.0033	0.661		Region Midwest	-0.0160	0.149	
Longitude coordinates	0.0003	0.533		Longitude coordinates	0.0012	0.017	*
Latitude coordinates	0.0001	0.767		Latitude coordinates	0.0004	0.402	
Spatial error term	0.5818	0.000	***	Spatial error term	0.4333	0.000	***
Pseudo R^2 0.51				Pseudo R^2 0.50			

* Models are fitted and corrected for heteroskedasticity.
Sources: Ministry of Health; Population censuses, IBGE.

Conclusion-Discussion

In this study, we aimed to elucidate the factors influencing the evolution of adult mortality in Brazil from 1980 to 2010. Our spatial analysis reveals that during the study period, the highest levels of adult mortality for both sexes were concentrated in the North and Southeastern regions, as well as the coastal areas of the Northeast. Despite the persistence of regional disparities in adult mortality, a discernible trend towards the convergence of adult mortality rates across the country is observed. Although specific areas in Brazil continue to exhibit mortality hotspots, adult mortality levels are progressively aligning across microregions. This phenomenon is particularly prominent among females.

Additionally, for both sexes, the models indicated a degree of spatial dependence, suggesting that the ${}_{45}q_{15}$ is not randomly distributed across microregions and is influenced by spatial factors (or unobserved local community elements). We also observed noteworthy associations between adult mortality and socioeconomic factors. For males, higher levels of unemployment were consistently associated with increased mortality. Conversely, increased schooling and urbanization were linked to reduced adult mortality rates for both genders.

For males, a distinct spatial trend dimension was identified with westward progression, particularly within the northern and northeastern regions of the country, extending towards smaller inland localities of Brazil. This spatial trend may correlate with the increasing prevalence of external causes of death that migrated from the Southeast to the Northeast of Brazil starting in the 1990s (Mendes et al. 2015), alongside escalating violence and homicides attributed to the expansion of organized crime or criminal factions into Brazil's interior (Paiva, 2019; Feltran et al., 2022; Duarte & Araujo, 2020).

Hence, these results reveal that social inequality accounts for regional variations in adult mortality for both genders. Moreover, unemployment and wealth inequality have a more pronounced impact on male adult mortality levels than on female ones. The findings suggest that socioeconomic disparities are the primary drivers of variability in adult mortality within the country. In the near future, these disparities could emerge as the primary explanation for differences in life expectancy, especially considering that infant and child mortality rates have displayed signs of convergence in recent years.

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