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Descriptive Finding

Analyzing regional patterns of mortality data quality and adult mortality for small areas in Brazil, 1980–2010

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Contents

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Abstract

BACKGROUND
Brazil's profound regional social inequalities raise concerns about their impact on adult mortality and data quality. Although the quality of mortality data has improved in recent decades, substantial regional disparities in death registration and mortality rates persist.

OBJECTIVE
Our study examines the spatial and temporal trends in death record quality and adult mortality across Brazil's small regions from 1980 to 2010. It assesses whether adult mortality rates are converging or diverging and whether the vital registration system is progressively improving.

METHODS
Utilizing mortality data and census records, we adopt a two-step approach. First, we evaluate data quality and calculate adult mortality estimates across subnational microregions using death distribution methods and TOPALS regression. Second, we employ bivariate choropleth mapping to explore the relationship between adult mortality and socioeconomic factors, measured across 558 microregions and disaggregated by sex.

RESULTS
Our findings highlight regional and temporal evolution of completeness of death count coverage. Results show that social inequality is a key factor driving regional disparities in adult mortality. Additionally, assessing and adjusting for the under-registration of death counts is crucial for understanding the spatial relationship between adult mortality and the distribution of socioeconomic inequality.

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CONTRIBUTION

We propose an approach combining demographic and statistical methods to evaluate data quality and produce adult mortality estimates for countries with limited data. We demonstrate how data quality evolves over time and how it varies by gender and region. This research offers a practical method for assessing data quality in small areas and estimating adult mortality in countries with data limitations, and it provides insights for policymakers aiming to reduce regional mortality disparities.

1. Introduction

In recent decades, Brazil has experienced a significant decline in mortality rates across various demographic groups, including infants, children, and adults (Szwarcwald et al. 2020; Barufi, Haddad, and Paez 2012; Sousa, Hill, and Dal Poz 2010; Queiroz et al. 2020a). This marked improvement in life expectancy at birth, from 1950 to 2020, has resulted in a substantial increase of approximately 25 years. It is important to highlight that this rate of progress exceeds that observed in many developed nations (Palloni and Pinto-Aguirre 2011; França et al. 2017; Alvarez, Aburto, and Canudas-Romo 2020).

Simultaneously, Brazil has experienced a long-term convergence in infant mortality rates, due in part to the reduction in the prevalence of infectious diseases (Barufi, Haddad, and Paez 2012). However, significant disparities in adult mortality persist across various subnational regions (Szwarcwald et al. 2020; Borges 2017; Schmertmann and Gonzaga 2018; Queiroz et al. 2020a). These enduring differences in mortality rates can largely be attributed to persistent inequities in income, as well as social and economic conditions (Fenelon 2013; Couillard et al. 2021; Ezzati et al. 2008; Rau and Schmertmann 2020). Notably, recent trends in life expectancy are increasingly shaped by variations in adult mortality, underscoring the importance of addressing these disparities and obtaining more accurate estimates at the local level.

Brazil has made substantial progress in the registration of death records in recent years. However, significant regional variations in data completeness persist (Diogenes et al. 2022; Queiroz et al. 2020b; Adair and Lopez 2018; Queiroz et al. 2017; Paes 2005), hindering comprehensive analyses of trends and determinants of adult mortality across different regions of the country (Diogenes et al. 2022; Bilal et al. 2019; Queiroz et al. 2020a; 2020b; Baptista and Queiroz 2019a; 2019b). Given the growing demand for studies on adult mortality in smaller areas, alternative approaches to obtaining reliable mortality estimates at the local level become essential. Analyses that do not account for the quality of data over time and across regions may mislead public policy decisions.

In this study, we compare adult mortality levels across 558 harmonized small areas of Brazil from 1980 to 2010, considering alternative approaches to adjusting death registration data. First, we assess the quality of the available data for these small areas and then generate adult mortality estimates by combining demographic and statistical methodologies. With these estimates, we analyze the association between adult mortality levels and socioeconomic conditions, measured by poverty, across regions.

2. Data and methods

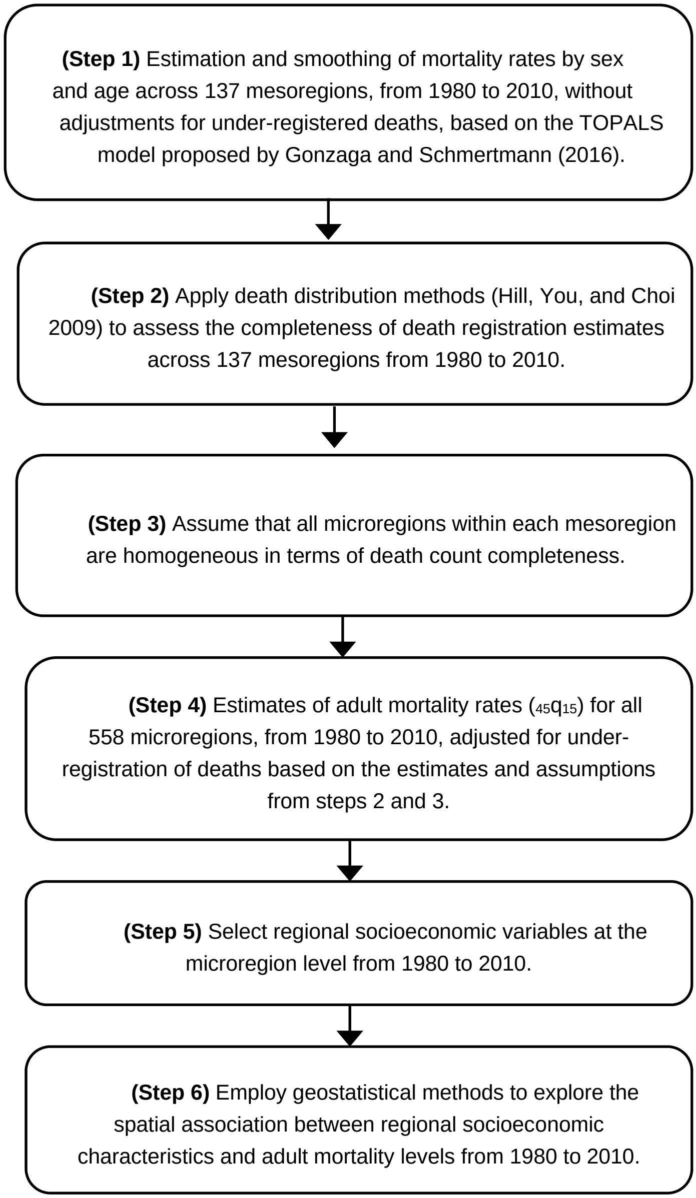
2.1 Death counts and population data

This study utilizes data from four population censuses conducted in Brazil in 1980, 1991, 2000, and 2010. Additionally, we incorporate data from the Ministry of Health's Mortality Information System (SIM in Portuguese). The SIM dataset provides comprehensive information on deaths, including causes of death categorized by age and sex, at the municipal level. Mortality data from 1980 were adjusted for missing age information by proportionally distributing the missing data across age groups (pro rata). To ensure consistency in geographic comparisons over time and to mitigate the effects of changes in municipal boundaries, we aggregated municipalities into comparable small areas, aligned with microregions delineated by the Brazilian Institute of Geography and Statistics (IBGE in Portuguese). These microregions are defined by the IBGE based on criteria such as geographic proximity and socioeconomic similarities. This approach enables us to track and analyze 558 distinct small areas in Brazil from 1980 to 2010.

2.2 Adult mortality estimates

The primary dependent variable in this analysis is the rate of death between ages 15 and 60, denoted as ${}_{45}q_{15}$, from 1980 to 2010. The use of ${}_{45}q_{15}$ is strategic, as it captures a substantial age range up to 60 years and mitigates challenges associated with mortality estimation at older ages while ensuring comparability with previous studies. This study builds upon the analyses of Queiroz et al. (2020a) and Gonzaga et al. (2024) by examining more finely disaggregated locations over an extended period, providing an in-depth exploration of the regional evolution of the vital registration system, and comparing analytical approaches to mortality differentials in Brazil. The analytical approach closely follows the methodology outlined in Queiroz et al. (2020a) and is described in Figure 1.

Figure 1: Flow chart of methodological steps used in the paper



First, we applied the TOPALS regression method (Gonzaga and Schmertmann, 2016; De Beer, 2012) to estimate smoothed adult mortality ($_{45}q_{15}$) for single ages. According to Gonzaga and Schmertmann (2016), TOPALS is a relational model that represents the sum of two functions: (1) mortality rates reflecting a standard pattern by age and sex, and (2) a linear parametric function between designated ages (knots) that captures the differences between the standard mortality function and the logarithm of the mortality function of the population of interest. The vector of logarithmic mortality rates for the population of interest is given by:

$$\lambda(\alpha) = \lambda^{*} + B\,\alpha \quad (1)$$

Here, λ is a 100 x 1 vector of log mortality rates for a mesoregion, λ^* represents the standard schedule (the national log mortality rate), B is a matrix of constants where each column corresponds to a linear B-spline basis function with knots defined at exact ages (x = 0, 1, 10, 20, 40, 70, 100), and α is a vector of parameters representing offsets from the standard schedule. In Equation (1) the α values represent additive offsets ($\lambda - \lambda^*$) to the log mortality rate schedule at the knots, between which the offsets change linearly with age. For any specific set of death and population data by age, the TOPALS method assumes that deaths are distributed as independent Poisson variables, which allows for the estimation of the α parameters.

Second, we applied death distribution methods (DDM) (Hill, You, and Choi 2009) to assess the completeness of death registrations across 137 mesoregions. A mesoregion is a subdivision within a Brazilian state, encompassing various microregions that share geographic, economic, and social similarities. These methods compare the age distribution of deaths to the age distribution of the population, allowing for the calculation of age-standardized mortality rates for a given period. The three main methods are: general growth balance (GGB) by Hill (1987), synthetic extinct generations (SEG) by Bennett and Horiuchi (1981), and the adjusted SEG by Hill, You, and Choi (2009). The GGB method, a generalization of the Brass balance equation, is applicable to nonstable populations and estimates both death registry coverage and relative census coverage. The SEG method adjusts future deaths using age-specific growth rates, allowing for greater flexibility in the stable population assumption. Hill, You, and Choi (2009) suggest that the SEG method is less sensitive to errors in age and population data but is more affected by migration than the GGB method. Murray et al. (2010), in their evaluation of 234 method variations, found that the SEG method (ages 55–70), the generalized GGB method (ages 40–70), and a combination of methods (ages 50–70) performed the best. Hill, You, and Choi (2009) recommend using a broader age range for GGB (ages 5–65) in combination with a narrower range for SEG (ages 50–70) for optimal results. We used the DDM R-package to estimate the levels of under-registration of death counts and to adjust mortality levels in each mesoregion. All estimates were generated using the combined GGB–SEG method, with age ranges automatically selected by the package.

Lastly, we adopt a simplifying assumption that all microregions within each mesoregion exhibit homogeneity in terms of death count completeness, thereby obviating the need for variability assumptions. This approach enables the use of mesoregion under-registration correction factors to adjust death counts and to yield adjusted adult mortality rates for all 558 microregions. Although we attempted to evaluate death count registration completeness at the municipal level across more than 5,500 municipalities, the assumptions underlying the methods were violated, leading to inconsistent estimates.

2.3 Bivariate maps

We employ bivariate choropleth mapping to investigate the spatial association between regional socioeconomic characteristics and adult mortality levels. These maps simultaneously display two variables and provide estimates of the degree and spatial pattern of cross-correlation between them (Baptista and Queiroz 2019b; 2022). Additional results and the syntax for replicating the analysis are available in the repository. In this paper, we present an analysis relating poverty levels and adult mortality. We performed a similar analysis using an inequality index and unemployment rates but decided to focus on poverty levels, which illustrate how this analytical approach can enhance the understanding of these issues and support the development of effective policies for assessing data quality and adult mortality.

3. Results

3.1 Estimates of adult mortality rates (${}_{45}q_{15}$)

Table 1 provides aggregated estimates of adult mortality and the completeness of death count coverage across the five regions of Brazil. Small-area estimates can be accessed in the repository (https://github.com/blanza/DataQualityMortalitySmallArea). Throughout the analyzed period, male adult mortality consistently surpasses female mortality in all regions. When considering the country as a whole, the ${}_{45}q_{15}$ for females declined from 0.121 in 1980 to 0.104 in 2010. In contrast, male adult mortality remained relatively stable over the period of analysis, at approximately 0.200, largely due to persistently high levels of deaths from external causes (França et al. 2017; Queiroz et al. 2020a). Notably, significant regional variations exist, with mortality decreasing in the Southeast and South but increasing in the Northeast and Midwest. In the North, the average ${}_{45}q_{15}$ remained relatively constant. Regarding the completeness of death count coverage, we observed an overall improvement for the country, though large regional disparities persisted over time. The results also reveal differences in data quality between males and females.

However, the large-area analysis obscures substantial regional differences, which are explored later in the paper.

Table 1: Adult probability of death ($_{45}q_{15}$) by sex, region/Brazil (1980–2010)

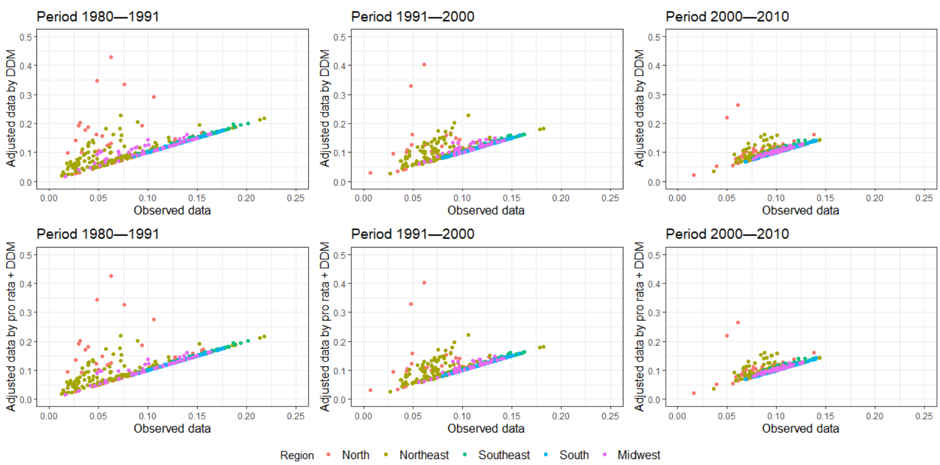
Region	Adult mortality and coverage of death counts					
	Female			Male		
	1980–1991	1991–2000	2000–2010	1980–1991	1991–2000	2000–2010
Brazil						
Mean	0.121	0.112	0.104	0.210	0.208	0.199
Minimum	0.017	0.027	0.022	0.023	0.073	0.099
Maximum	0.425	0.402	0.265	0.677	0.512	0.318
Total of areas	548	558	558	548	558	558
Coverage of death counts	0.906	0.923	0.939	0.909	0.925	0.950
North						
Mean	0.125	0.105	0.102	0.207	0.184	0.182
Minimum	0.027	0.031	0.022	0.052	0.073	0.099
Maximum	0.425	0.402	0.265	0.677	0.512	0.313
Total of areas	57	64	64	57	64	64
Coverage of death counts	0.772	0.820	0.863	0.777	0.816	0.872
Northeast						
Mean	0.096	0.102	0.102	0.171	0.185	0.186
Minimum	0.020	0.027	0.036	0.023	0.079	0.106
Maximum	0.219	0.222	0.160	0.409	0.353	0.317
Total of areas	186	188	188	186	188	188
Coverage of death counts	0.816	0.856	0.898	0.822	0.869	0.936
Midwest						
Mean	0.107	0.113	0.106	0.183	0.213	0.211
Minimum	0.017	0.060	0.079	0.023	0.132	0.176
Maximum	0.163	0.148	0.129	0.289	0.372	0.267
Total of areas	51	52	52	51	52	52
Coverage of death counts	0.933	0.957	0.966	0.937	0.939	0.942
South						
Mean	0.131	0.116	0.103	0.230	0.217	0.200
Minimum	0.085	0.080	0.069	0.131	0.160	0.149
Maximum	0.176	0.160	0.142	0.287	0.275	0.245
Total of areas	94	94	94	94	94	94
Coverage of death counts	0.999	0.997	0.993	0.999	0.996	0.992
Southeast						
Mean	0.146	0.124	0.109	0.254	0.239	0.218
Minimum	0.090	0.086	0.081	0.150	0.154	0.173
Maximum	0.201	0.163	0.141	0.337	0.349	0.318
Total of areas	160	160	160	160	160	160
Coverage of death counts	0.994	0.988	0.978	0.994	0.987	0.977

Source: Ministry of Health; population censuses, IBGE.

3.2 Comparison of adjusted and observed estimates of adult mortality

Figure 2 presents a comparison of adult mortality ($_{45}q_{15}$) for females using both observed data and estimates derived from our approach. The first row displays estimates adjusted using our proposed method, while the second row provides results adjusted for missing age information. Each colored point represents a microregion, with the color indicating the macroregion to which it belongs. The y-axis shows adjusted mortality estimates, while the x-axis shows the rate of death based on unadjusted observed data. As previously discussed, Brazil exhibits significant regional heterogeneity in both economic and social terms.

Figure 2: Comparison of adult mortality – observed and adjusted data, females, 1980 to 2010, by microregion



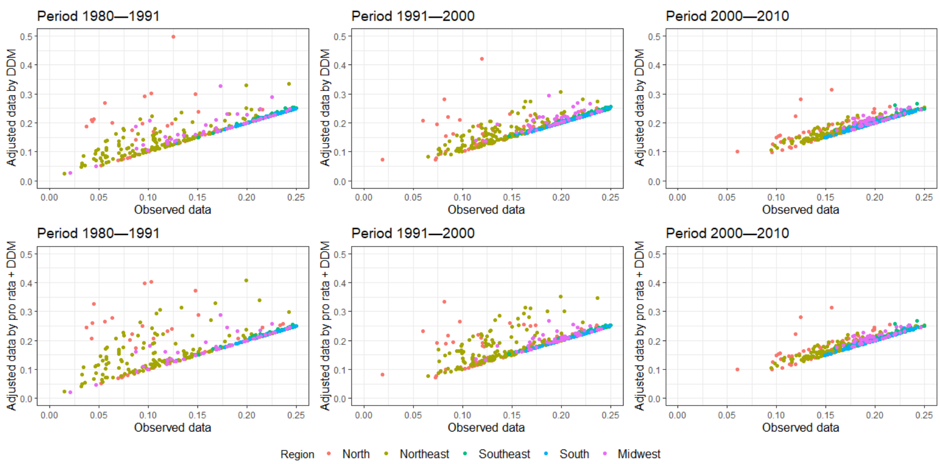
Source: Ministry of Health; population censuses, IBGE.

Several notable and significant outcomes can be observed in Figure 2. The results indicate a continuous decline in female adult mortality over time. More importantly, they also demonstrate an improvement in data quality both over time and across regions. In the 2000–2010 period, most points are closer to the 45-degree line compared to 1980–1991, reflecting improvement in data. Throughout the analysis, regions with poorer data quality are concentrated in the North and Northeast, also characterized by lower socioeconomic indicators. It is important to emphasize that mortality data from the South and Southeast have maintained a high level of quality over the past 30 years, as the relationship between observed and adjusted data consistently aligns with the 45-degree line, indicating reliable registration practices.

Figure 3 presents the same information for males. A decline in adult mortality levels is also observed, though at a much slower pace compared to females, alongside improvements in data quality. The higher levels of male adult mortality are largely attributed to deaths from violence and traffic accidents (Aburto et al. 2021; Calazans, Guimarães, and Nepomuceno 2023).

In the case of males, we observed greater improvements compared to females, with very few regions deviating from the 45-degree line. In all areas, there was an increase in the completeness of death count coverage. Our findings align with other studies in Latin America (Castanheira and Monteiro da Silva 2022; Peralta et al. 2019) that highlight a pattern of sex differentials in the evolution of death count coverage across Brazilian regions, with larger disparities observed in the North and Northeast. It should be noted that the coverage of female death counts was of better quality than that of male death counts in the first two periods. However, improvements in male death counts in more recent periods have reversed this situation. We argue that much of the difference may be attributed to the composition of causes of death. A significant proportion of male deaths between the ages of 15 and 60 are due to external causes, which require official investigation and, consequently, lead to more accurate registration (Lima et al. 2021).

Figure 3: Comparison of adult mortality – observed and adjusted data, males, 1980 to 2010, by microregion

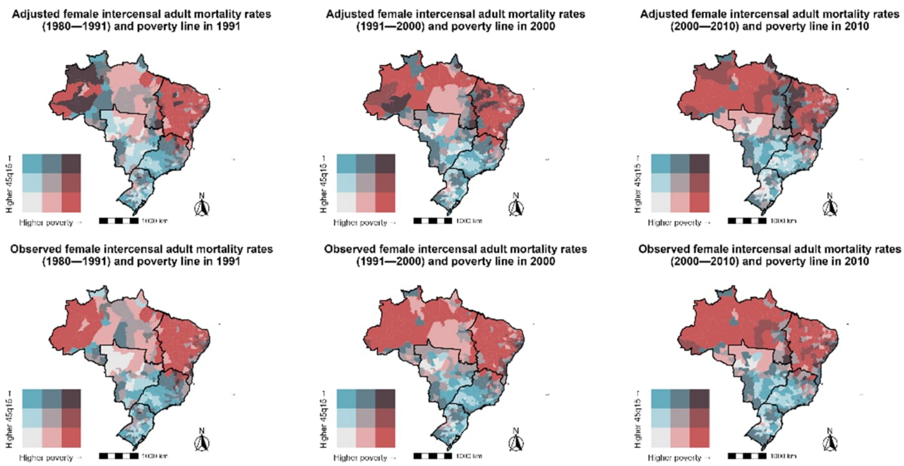


Source: Ministry of Health; population censuses, IBGE.

3.3 Data quality and socioeconomic differentials in adult mortality

Using bivariate maps, Figure 4 illustrates the relationship between female adult mortality rates and the proportion of the population living below the poverty line. Bivariate mapping techniques utilize a combination of selected colors to effectively communicate the spatial information of the map. The legend grid cells incorporate varying shades to depict the relationship between adult mortality rates and poverty levels across different microregions. The x-axis employs a gradient of red hues, ranging from light to deep red, representing low to high proportions of the population living in poverty. Similarly, the y-axis uses shades of blue, progressing from light to dark, to indicate a range from low to high levels of adult mortality. The diagonal cells illustrate the intersection of these two variables. For example, a dark purple cell signifies an area with high levels of both adult mortality and poverty, whereas a light gray cell indicates a region with low levels of both indicators.

Figure 4: Female adult mortality ($_{45}q_{15}$) and poverty levels in Brazil, 1980–2010; adjusted and observed data



Source: Ministry of Health; population censuses, IBGE.

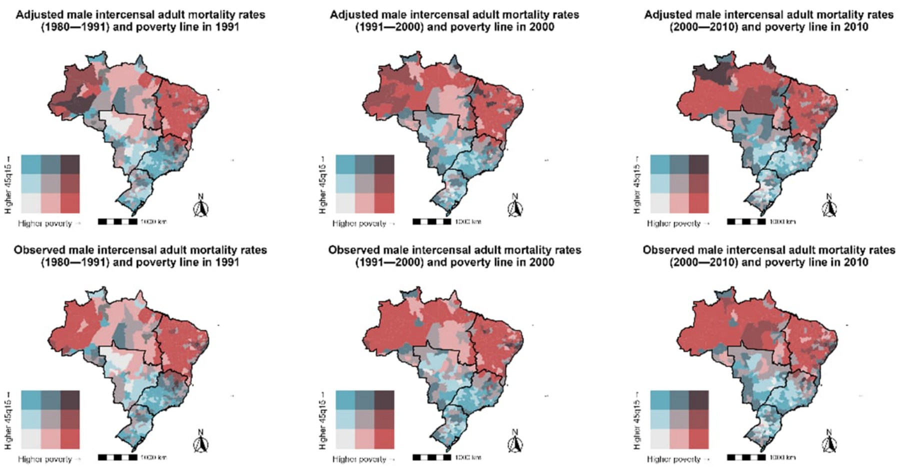
To categorize the results appropriately, we computed 1/3 quantiles for both variables. As a result, microregions were assigned to the corresponding class based on their levels of mortality and poverty. We chose to focus on poverty due to the extensive literature on the relationship between these two variables (Ichihara et al. 2022; Fritzell et al. 2015; Soares 2007a; 2007b). Similar analyses were conducted for other socioeconomic variables (not shown here due to the scope of the work), but the primary focus remains on poverty. Additional analysis, available in the GitHub repository, uses other socioeconomic variables, such as unemployment rates.

The most significant finding from the bivariate maps is the importance of assessing the quality of mortality data across regions and applying appropriate methods to adjust mortality levels. The second row of maps displays the association without accounting for or correcting the completeness of death count coverage. Based on these unadjusted results, one might incorrectly conclude that regions with high poverty levels in Brazil, throughout the analysis period, are associated with lower mortality levels. However, the analysis conducted with adjusted data reveals a different outcome. We observe that many regions with higher poverty levels are, in fact, associated with higher female mortality rates – particularly in the North and Northeast.

Between 1980 and 1991, the highest levels of adult mortality for both sexes were concentrated in the North and Southeast, as well as along the coastal areas of the Northeast. Despite fluctuations in the female-to-male adult mortality ratio over time, there is a discernible trend toward the convergence of ${}_{45}q_{15}$ across the country. Although certain areas in Brazil continue to exhibit mortality hot spots, adult mortality levels are gradually becoming more uniform across microregions. This trend is particularly pronounced among females.

Figure 5 shows the same relation for males. The results are very similar to what is observed for females. When we adjusted estimates for the level of completeness of death count coverage, in some regions that had low mortality in high poverty areas, the relation changed. That is, regions with higher mortality are in areas with higher poverty levels. However, since data quality for females was worse than for males during the period of analysis, the impact of the adjustments is greater for females.

Figure 5: Male adult mortality (${}_{45}q_{15}$) and poverty levels in Brazil, 1980–2010, adjusted and observed data



Source: Ministry of Health; population censuses, IBGE.

4. Discussion

This study employs a replicable methodology to assess data quality in mortality records and generate adult mortality estimates for small areas. This methodology can be applied in countries lacking robust civil registration and vital statistics (CRVS) systems, as well as in countries that inquired about household deaths in recent censuses or surveys. We utilize a combination of traditional demographic methods (DDM) and the TOPALS regression model to evaluate data quality and produce adult mortality estimates for all microregions of Brazil from 1980 to 2010. Our findings highlight the gender and regional disparities in death count registration, a pattern also observed in other countries, such as Peru and Ecuador, where the completeness of death records is correlated with income levels and inequality (Peralta et al. 2019; Castanheira and Monteiro da Silva 2022).

Our results also identify significant improvements in mortality data quality over time and across regions of the country. The analysis comparing observed data with adjusted data reveals a reduction in the dispersion of mortality levels in both datasets. In the most recent period, 2000–2010, most points lie closely around the 45-degree line. However, the pace of improvement for males is faster than that for females, indicating a notable difference in the quality of registration by sex, as observed in other countries (Peralta et al. 2019; Castanheira and Monteiro da Silva 2022).

Our results add to previous research that examined data quality for states and other regions of the country. For instance, Diogenes et al. (2022) explored and analyzed death records from 2010 utilizing three data sources: the Mortality Information System, the Civil Registry, and the 2010 Demographic Census. They found a strong association between the socioeconomic characteristics of municipalities and the information source reporting a higher number of events. The study indicates that the 2010 census captured more deaths than the Mortality Information System and Civil Registry, particularly in less developed areas of the country.

Furthermore, our study contributes to the argument that social, economic, and demographic factors can account for the spatial distribution of adult mortality. To our knowledge, and due to data limitations, most research on mortality differentials across regions has primarily focused on developed, high-income countries (Fenelon 2013; Vierboom, Preston, and Hendi 2019; Rau and Schmertmann 2020). There has been a dearth of such analyses in the context of countries with incomplete or deficient data systems (Queiroz et al. 2020a; Peralta et al. 2019; Castanheira and Monteiro-Silva 2022; Baptista, Queiroz, and Pinheiro 2021). Nevertheless, these analyses are pivotal for the formulation of effective health policies aimed at reducing mortality levels and enhancing population health (Bilal et al. 2021).

We argue that external causes of death may underlie this spatial dependence, as they are the primary causes of death among young males in Brazil. Historically concentrated in the Southeast, these deaths have progressively shifted toward the Northeast, particularly in coastal areas. This finding highlights the dynamic nature of male adult mortality across the regions of the country (Aburto et al. 2021; Baptista, Queiroz, and Pinheiro 2021; Ingram and Marchesini 2017; Moura et al. 2015). The observed decline in female adult mortality across all regions from 1980 to 2010 is a critical factor in explaining the widening male–female gap in life expectancy at birth. This trend underscores the varying impact of causes of death on changes in life expectancy across regions of Brazil and aligns with trends observed in more developed countries (Kibele 2012; Rau and Schmertmann 2020; Vierboom, Preston, and Hendi 2019; Couillard et al. 2021).

In conclusion, the descriptive findings illuminate regional disparities in data quality within the country and their evolution over recent decades. Future research agendas should address questions related to how health measures are adapting to an aging population and changes in population behavior. Ultimately, this study emphasizes that despite consistent improvement in the quality of Brazilian death records over the past few decades, there remains significant potential for enhancing vital registration in certain areas of the country. While methodological advances have been made and various estimates are available in the literature, these improvements have limitations and cannot substitute for a high-quality vital statistics recording system. Therefore efforts should focus on producing high-quality records, including the accurate documentation of causes of death, to yield more reliable mortality estimates and enhance our understanding of trends and differentials in various developing countries (Silva 2022).

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