# Temporal and Spatial Patterns of Mortality Gender Gap in Developing Countries: evidence from Brazil from 1980 to 2022

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## Abstract

### Background

Brazil exhibits one of the widest and most persistent gender gaps in life expectancy among developing countries. From 1980 to 2024, the gap widened from 3.2 to nearly 8 years, reflecting complex inequalities in health behavior, access to care, exposure to violence, and socioeconomic conditions. While previous studies have explored gender differences in infant and young adult mortality, fewer have examined prime-aged adult mortality (15–60 years), despite its relevance for understanding labor force health and the impacts of social policy. This study investigates temporal and spatial patterns of adult mortality by sex across Brazil's meso-regions from 1980 to 2022, emphasizing how regional contexts shape the evolution of the gender gap.

### Data and Methods

Adult mortality data were drawn from the Ministry of Health's DATASUS system (1979–2022) and population estimates from IBGE. To address underreporting and quality issues, especially in the North and Northeast, mortality estimates were corrected using death distribution methods. The analysis focused on the probability of dying between ages 15 and 60 (45q15) and the male-to-female mortality ratio as the gender gap indicator. Temporal trends were assessed using relative pace-of-change metrics, while spatial heterogeneity was evaluated through bivariate choropleth mapping and Lee's (2001) bivariate spatial correlation index at the meso-regional level (n=137).

### Results

Between 1980 and 2022, female adult mortality rates declined from 0.14 to 0.09, while male mortality decreased from 0.23 to 0.19, widening the average gender gap from 1.72 to 2.07. Spatially, the gap first intensified in the South and Southeast, particularly in urbanized and economically advanced coastal regions, while smaller gaps persisted in high-mortality areas of the North and Northeast. Bivariate analyses revealed a strong negative correlation between the gender gap and female mortality levels, suggesting that men in lower-mortality regions have not shared equally in health gains.

### Conclusion

Brazil's widening adult mortality gender gap reflects uneven health improvements and structural inequalities. Men remain disproportionately affected by external causes, behavioral risks, and limited preventive care. Targeted interventions addressing male-specific vulnerabilities—particularly in regions with rapid female health gains—are crucial to reducing gender-based mortality disparities and promoting equitable health progress across regions.

## Introduction

Brazil continues to exhibit large and persistent gaps in life expectancy at birth, The gender gap in life expectancy in Brazil, which usually favored women, has widened from approximately 3.2 years in 1980 to around 7 to 8 years by 2024 (WPP, 2024). For example, in 1980, women lived about 64.19 years on average, compared to men at 59.5 years. By 2023, life expectancy was approximately 72.7 years for men and 78.9 years for women. These disparities reflect inequalities and differences in health behaviors, access to healthcare, living conditions, education, and exposure to violence and other health risks (Abreu, Cesar and França, 2009; Moura et al., 2016).

In recent years, there are several studies looking at mortality gender differences and at life expectancy at birth, young adult and infant and child mortality (Abreu, Cesar and França, 2009; Alves and Coelho, 2021; Costa, Silva and Victora, 2017; Souza, 2023; Moura et al, 2016). Much less attention is paid to mortality differences for prime-aged adults, ages 15 to 60, those that have already observed some decline in mortality risks by external causes of deaths, and have not reached old ages yet. The study of mortality differences for this age group is also relevant to understanding their health conditions (Berbel and Chirelli 2020), as this group might be impacted by further pension reforms.

In Brazil, a growing body of researches has analyzed mortality at the national and state levels (Sauerberg et al, 2023; Spijker, van Poppel, and van Wissen, 2007; Wang, 2013), but far less is known about the dynamics of adult mortality in smaller areas, especially in the case of Brazil. For instance, studies for different countries and developed regions identify significant heterogeneity in the mortality gender gap. Thus, is it important to understand how these patterns evolved over time? Where are the differences most extreme? And critically, are there identifiable regional or structural mortality patterns?

One striking and underexplored aspect of mortality inequality in Brazil is the persistent gender gap in adult mortality—particularly due to the fact that men are not sharing equal health improvements as seen among women (Cobo, Cruz and Dick, 2021; Azevedo-Barros et. al, 2016). One of the main reasons to explain the large differences between male and female mortality is the levels of external causes among men, but among older adults external causes are not the main cause of the death and other causes play an important role (França et al. 2017; Feraldi & Zarulli, 2022). This analysis reveals a consistent and troubling trend: in areas where female adult mortality is becoming low, the gender gap is large and stable over time, indicating that men are not experiencing the same health gains as their female counterparts. On the other hand, in regions where female mortality is high—often reflecting worse health and social conditions overall—the gender gap tends to be smaller, suggesting that poor health environments affect both sexes more equally.

This pattern has critical implications. It suggests that in regions where public health advances, women have benefited from it, men have been largely left behind—potentially due to behavioral factors, exposure to violence, weak access to preventive care, or labor-related risks. The result is a widening inequality between men and women within populations that experience increases in life expectancy (Wang et al. 2012).

These findings add a new dimension to our understanding of health inequality in Brazil. They highlight not only the spatial disparities in mortality but also a deep and persistent problem with men's health that standard indicators can obscure. Without targeted policies addressing the specific vulnerabilities of adult men—particularly in regions where female health has improved—these internal gaps are likely to persist or even worsen.

## Methodology and Data

Death Counts and Population Data

We make extensive use of the Ministry of Health database, DATASUS (avaliable at http://www2.datasus.gov.br). The database provides information on death counts, causes of deaths, by age and sex, at the municipality level. All-cause mortality has been available since 1979, mortality data is organized using codes from the ICD Revision (9th from 1980 to 1995 and 10th from 1996 on). Data cleaning and compilation is done at the municipal and state levels, and an electronic data file is transferred to the national office every 3 months. Population by age and sex, at the local level, comes from the Brazilian Censuses and from IBGE estimates. The Ministry of Health data (DATASUS) is publicly available.

Historically, states of the North and Northeast observed lower mortality coverage and worse quality of death registration in relation to the states of the Southeastern and Southern of the country (Queiroz, et. al. 2020; Queiroz, et.al 2017, Lima and Queiroz, 2014). Since the 2000s, however, there has been an impressive improvement in both quality issues (Queiroz, et. al 2020; Queiroz, et.al 2017). To produce the estimates of adult mortality, correcting for death counts registration, we used the approach proposed by Queiroz, et.al (2020) and Lima et. al (2024). The improved quality of mortality information in the North / Northeast has radically altered the trends, mainly due to noncommunicable diseases. Several articles argue and show that the quality of the information has improved since it allows an adequate comparison between the regions (Borges, 2017; França, et.al, 2017).

To keep temporal comparability, we aggregated municipalities by comparable small areas, using the IBGE definition of comparable meso-regions (137 localities in total). These regions are constructed utilizing regional and socioeconomic similarities (IBGE, 2025). The meso-regions serve only for statistical purposes; therefore, they do not represent a political or administrative entity. The main advantage of working with these comparable areas is that they have not changed their boundaries over the period of analysis, making us able to follow and study 137 small areas between 1980 till 2022.

Gender Gap

In this paper, we use the traditional measure of gender gap that is the ratio of male mortality to female mortality. We analyze the adult mortality gender gap focusing on the probability of dying from ages 15 to 60 years old. The reasons for choosing this age group are twofold: first, the gender gap for the prime-age adults is less studied, and a lot of the changes in mortality in the country are happening in this age group. Second, age 15 is the assumed age of entry into adulthood being the turning point at which declining childhood mortality risks are replaced by increased mortality risks for young-adult age groups, and covers a substantive age-range up to age 60, avoiding problems inherent in mortality estimates at more advanced ages (Schmertman et al, 2024).

Pace of Change in adult mortality rates

Additionally, we also estimated the pace of changes of adult mortality rates. To measure the pace of change in demographic variables, we estimate the relative change of the indicator 45q15. The relative derivative, or pace of change, can be approximated as:

$$\frac{\dot{v}}{v} \approx \frac{\ln\left(\left[\frac{v(t_2)}{v(t_1)}\right]\right)}{(t_2 - t_1)} \quad (1)$$

Where, $(t)$ is the indicator of interest at time $t$, and two values are needed for its relative change between the beginning and the end of each period ($t1$ and $t2$, respectively). This measure is particularly useful when comparing areas with different starting mortality levels, capturing the proportional intensity of change.

Spatial Analysis

We used R software, first, to create descriptive and bivariate choropleth maps, and to evaluate the degree of relationship between gender gap and trends in female adult mortality at the meso-region level. To match the nine different colors with appropriate classes, we calculate 1/2-quantiles for both variables. Then, the countries are put into the appropriate class corresponding to their average estimate of the gap and the preferred measure used to indicate trends in female adult mortality.

Unlike the univariate choropleth map, which uses colors that portray the spatial variation of a single attribute, bivariate choropleth maps display *two variables* simultaneously (Cartensen 1986). The bivariate map goes further and allows us to estimate the degree or spatial pattern of cross-correlation between variables, something that, as far as we know, is still little explored in demographic and health studies. Hence, the resultant map provides useful information that allows one to quickly identify target areas for resource allocation decisions or health interventions.

Lee index for bivariate spatial analysis

As part of our second exploratory analysis, we applied the bivariate *Lee* index, as developed by Lee in 2001. Lee (2001) introduced an index designed to assess spatial associations between two variables, offering a parametric measure of bivariate spatial dependence. Similar to Moran's *I*, Lee's statistic provides both a global index ($L_{xy}$) and a Local index (Lee 2009). But its interpretation is more straightforward than the Moran index, because this bivariate estimate combines a Pearson's correlation coefficient with a spatial component. Therefore, the estimated Lee *I* correlation indicates that in a spatial *i* unit positive values present a strong positive spatial correlation between two variables (Lee 2001, 2009). The Lee index (L) is computed by multiplying two z-scores by their respective means and standard deviations and is determined using Equation 1:

$$L_{X,Y} = \frac{\sum_i (\tilde{x}_i - \bar{x})(\tilde{y}_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2} * \sqrt{\sum_i (y_i - \bar{y})^2}} \quad (2)$$

Where, $\tilde{X}_i$ and $\tilde{Y}_i$ are the elements for location $i$ in $X$ and $Y$ in the spatially lagged vectors, $\bar{X}_i$ and $\bar{Y}_i$ are the mean values of the attribute, and $X_i$ and $Y_i$ are the attribute values at location $i$.

**Preliminary results**

Table 1 presents descriptive statistics for the country in the period of analysis. We show adult mortality estimates and gender gaps for each one of the time periods. The results show that on average the gender gap is increasing from 1980 to the most recent period, from 1.72 to 2.07, and this mortality gap is mostly explained by the faster decline in female mortality compared to males. In the same period, female adult mortality reduced from averages of 0.14 to 0.09, as males' mortality also declined but in a higher level from 0.23 to 0.19 on average.

**Table 1**: **Statistics of 45q15 ratios (gender gap) and 45q15 for sexes, meso-regions, Brazil, 1980-2022.**

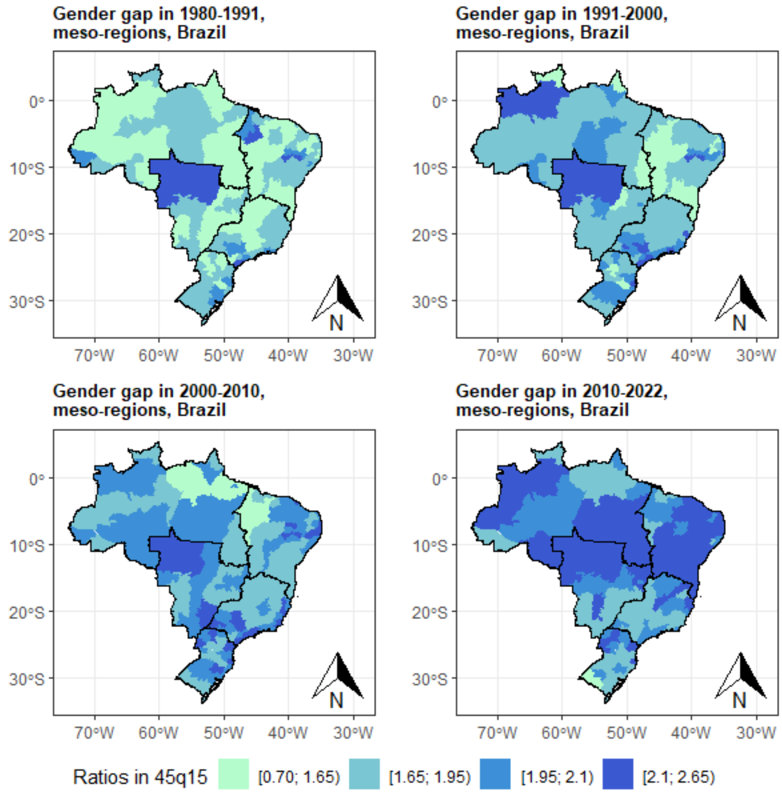
| | Statistics in period 1980-1991 | | | | | |
|---|---|---|---|---|---|---|
| Measure | Min. | 1st Q. | Median | Mean | 3rd Q. | Max |
| 45q15 males | 0.1 | 0.19 | 0.24 | 0.23 | 0.27 | 0.45 |
| 45q15 females | 0.07 | 0.11 | 0.13 | 0.14 | 0.15 | 0.38 |
| Gender gap | 0.71 | 1.6 | 1.74 | 1.72 | 1.87 | 2.28 |
| | Statistics in period 1991-2000 | | | | | |
| Measure | Min. | 1st Q. | Median | Mean | 3rd Q. | Max |
| 45q15 males | 0.11 | 0.18 | 0.22 | 0.22 | 0.24 | 0.34 |
| 45q15 females | 0.06 | 0.1 | 0.11 | 0.12 | 0.13 | 0.29 |
| Gender gap | 1.15 | 1.75 | 1.86 | 1.87 | 2.02 | 2.38 |
| | Statistics in period 2000-2010 | | | | | |
| Measure | Min. | 1st Q. | Median | Mean | 3rd Q. | Max |
| 45q15 males | 0.13 | 0.19 | 0.21 | 0.21 | 0.23 | 0.29 |
| 45q15 females | 0.07 | 0.1 | 0.11 | 0.11 | 0.12 | 0.14 |
| Gender gap | 1.27 | 1.85 | 1.99 | 1.96 | 2.08 | 2.33 |
| | Statistics in period 2010-2022 | | | | | |
| Measure | Min. | 1st Q. | Median | Mean | 3rd Q. | Max |
| 45q15 males | 0.13 | 0.17 | 0.19 | 0.19 | 0.20 | 0.25 |
| 45q15 females | 0.06 | 0.08 | 0.09 | 0.09 | 0.10 | 0.12 |
| Gender gap | 1.60 | 1.90 | 2.06 | 2.07 | 2.21 | 2.61 |

Source: Own estimates based on DATASUS (2025)

However, a large spatial variation across meso-regions is also observed, as measured by following statistical analysis. Figure 1 shows a more granular analysis presenting estimates for 137 comparable small areas in three different periods of time. The results indicate that in the 1980s the gender mortality gap was closer to 1 in most of the meso-regions of the country, and some areas presenting superior values—indications of higher male than female mortality.

Over the period of analysis this gender mortality gap increased for most of the regions in the country, and a rise in concentration of regions with ratios above 2, indicating that males' adult mortality levels was twice higher as observed for females. It is also interesting to notice the increasing in 45q15 male/female ratio in the coastal areas of the Southeast, Rio de Janeiro, and the state of São Paulo, in 1991-2000, and the spread further South and several regions of Midwest, North and Northeast during the last intercensal period of 2010-2022.

**Figure 1 – Gender Gap in Adult Mortality, meso-regions, Brazil, 1980 – 2022.**

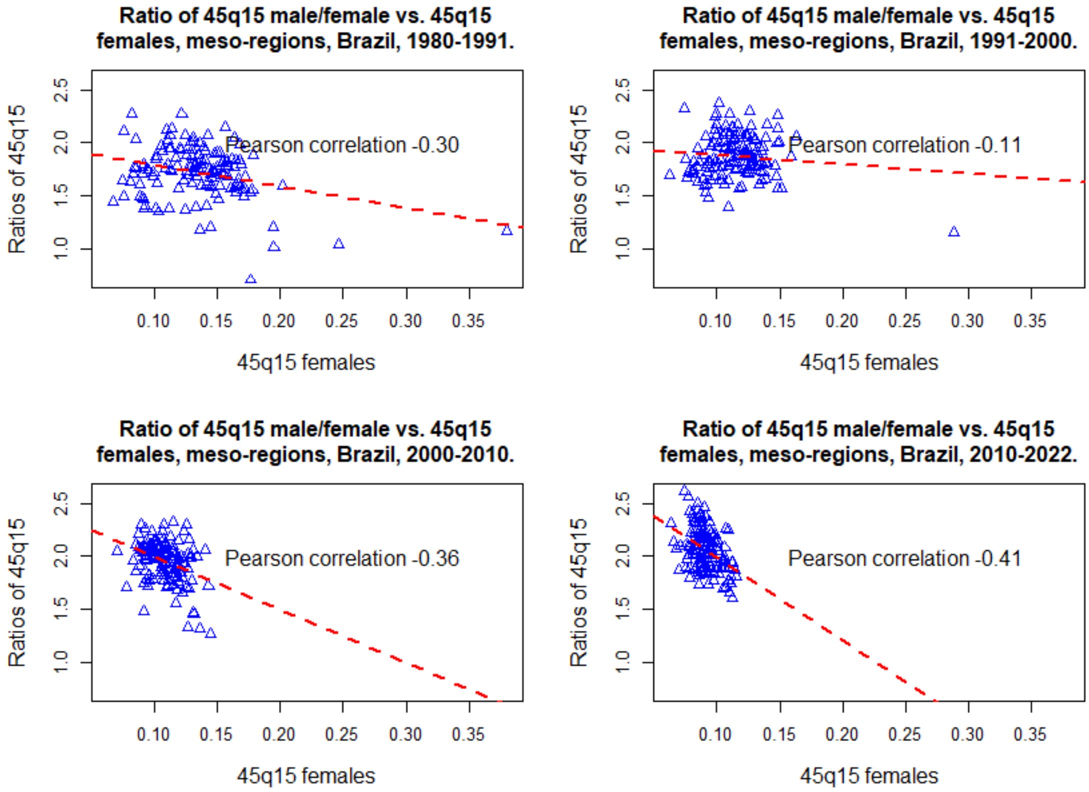



Source: Own estimates based on DATASUS (2025)

Figure 2 shows the relationship between the gender gap (male/female ratio) to the level of female adult mortality in each area. In each period, the results show a negative relationship, which seems to increase over time, indicating that the adult mortality gender gap is smaller in areas with higher female mortality, and larger differences in adult death rates between sexes is encountered in areas where female mortality is lower.

This finding may indicate that males are not enjoying the same health benefits of females in several areas of Brazil, and that areas with small adult mortality gender gaps are more related to high mortality among both sexes instead of reductions in overall mortality.

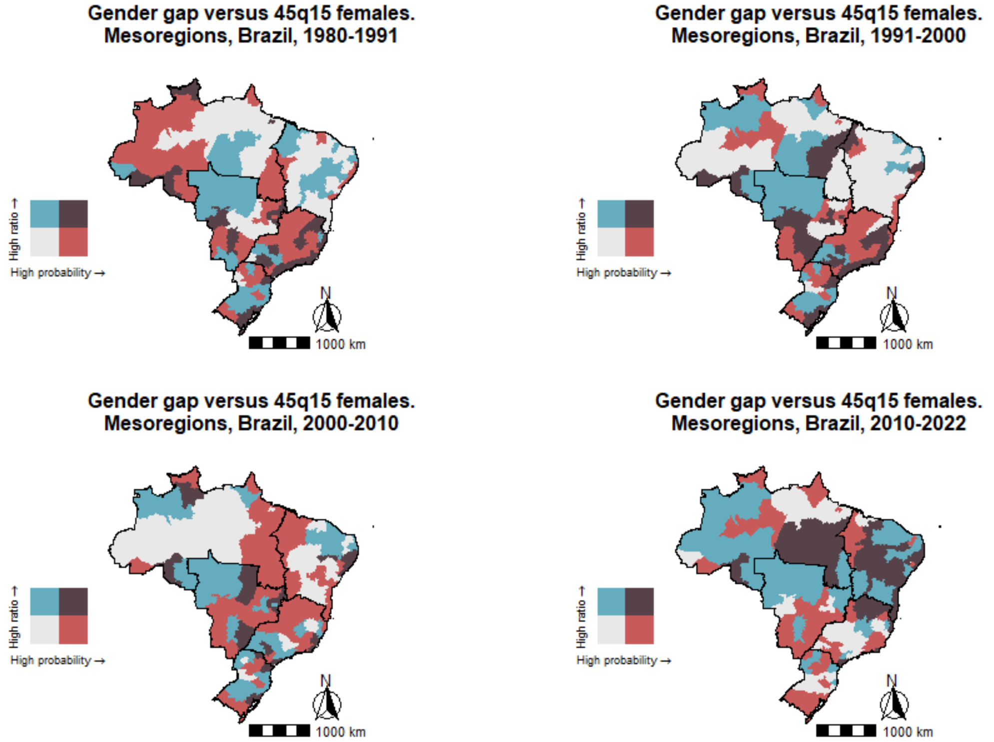
**Figure 2 – Scatter Plot – relation to gender gap and female adult mortality rates, meso-regions, Brazil, 1980 – 2022.**




Source: Own estimates based on DATASUS (2025)

Additionally to the scatterplot, Figure 3 shows the bivariate maps to help identify those areas. Using bivariate maps, it is possible to identify areas with different patterns of relationship. On one hand, in dark grayish-purple colors, we see isolated points of the country and the coastal areas in the Southeast are characterized by high levels of gender gap and female adult mortality, especially during the periods of 1980-1991 and 1991-2000. During the period of 2000-2010, the same pattern is seen in some coastal locations of Northeast of the country, and in the last intercensal period of 2010-2022 there is also noticed many areas with these characteristics in the Northern and Northeastern parts of the country. On the other hand, areas marked as sky-blue indicate regions with high mortality gender gap and low adult female mortality, suggesting that female benefited from health interventions where males did not. It is noticeable an increase in areas with these characteristic between the 1980 and 2022.

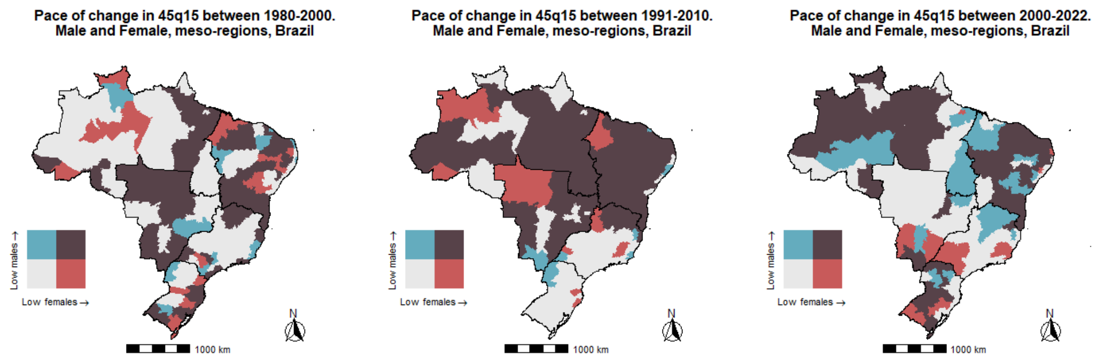
**Figure 3 – Bivariate Maps – relation to gender gap and female adult mortality, meso-regions, Brazil, 1980 – 2010.**




Source: Own estimates based on DATASUS (2025)

Figures 4 and 5 show the association between male and females paces of mortality decline. In the maps, lower pace indicates slow mortality declines in the periods of analysis. Hence, light gray color areas indicate very fast pace of mortality decline for both males and females, where dark grayish-purple areas indicate slower mortality decline for both sexes.

**Figure 4 – Bivariate Maps – pace of adult mortality decline for males and females, Brazil, 1980 – 2022.**

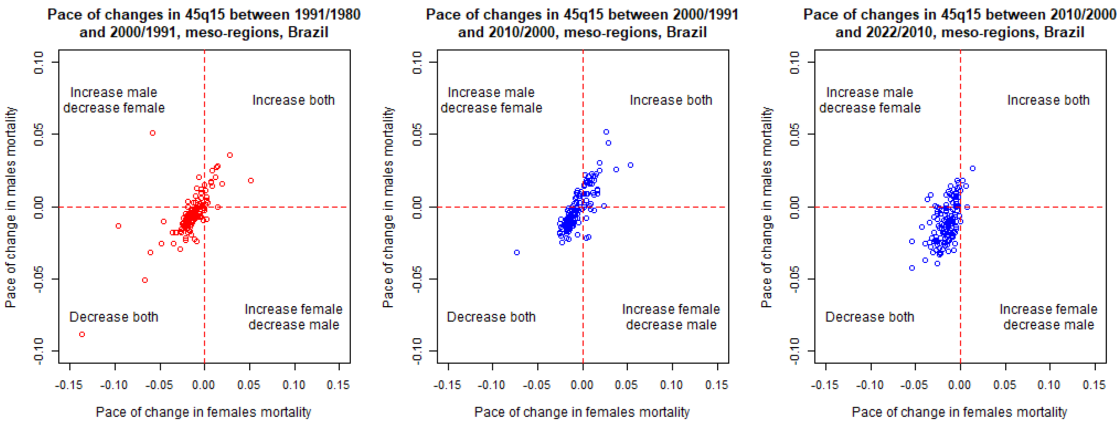



Source: Own estimates based on DATASUS (2025).

Not surprisingly, regions with higher levels of mortality depicted the lower rates of decline. This analysis also helps to identify regions where female mortality declined faster, and males still show slow paces of mortality rates decline (colors in sky blue). These areas were located mostly in the Northern and Northeastern parts of the country, especially in the last period between 2000 and 2022. Moreover, in the same period, we also observed that there are a few areas whereas male mortality declined faster than females (red colors), and the gap remained in high levels, such as parts of the Midwest, South and Southeast of the country.

Figure 5 complements the maps and show the pace of mortality change in four quadrants for different periods of analysis. Between the first and last periods, we notice many important things. First, the number of areas whereas mortality is increasing for both sexes is reducing and, second, almost no meso-region present positive pace of mortality changes for females and negative for males.

**Figure 5: Pace of changes in adult mortality for both sexes in each period, meso-regions, Brazil.**




Source: Own estimates based on DATASUS (2025).

Third, we also notice an increase number of areas whereas both genders are experiencing faster decreasing mortality. Finally, there are also many areas with increasing pace of female mortality reduction as slower speed of changes in males' mortality.

## Discussion and further work

The findings of this study illuminate the evolving landscape of gender disparities in adult mortality across Brazil's meso-regions, revealing a widening gender gap in life expectancy and persistent health inequalities. From 1980 to 2022, the average male-to-female mortality ratio for ages 15–60 increased from 1.72 to 2.07, primarily due to faster reductions in female mortality (from 0.14 to 0.09), and slow decreases for males (0.23 to 0.19). This trend aligns with broader literature on Brazil's health transition, where improvements in data quality and public health initiatives have accelerated mortality declines, but unevenly. The negative correlation between the gender gap and female mortality levels is particularly striking: larger gaps in low-female-mortality regions (e.g., Southeast coastal areas) suggest that men are not benefiting equivalently from advancements in health. Conversely, smaller gaps in high-mortality areas (e.g., North/Northeast) indicate shared vulnerabilities, where socioeconomic deprivation and limited infrastructure that affect both sexes.

The concentration of high-gender-mortality gap areas expanded from the 1980s to the 2020s, particularly in the South and Southeast, suggest economic development has benefited women's health more. In contrast, slower declines for both sexes in the North/Northeast could reflect historical under-registration and ongoing challenges like non-communicable diseases. The pace-of-decline maps show that while overall mortality reductions accelerated, female paces outstripped males in many regions, contributing to a wide gap. Although the 'normal' causes of the male mortality exists, where smoking, alcohol consumption, cardiovascular illness and risk-taking cause wide gender differences exist, but in Brazil, external causes—such as homicides and accidents—play a dominant role for prime-aged men. Violence, drug-related crimes and transport accidents matter a lot in urban areas, and the differences are amplified by gender norms that discourage men from seeking care.

These patterns have profound implications for policy and equity. Standard life expectancy metrics mask intra-regional gender inequalities, potentially leading to complacency in "improving" areas. Targeted interventions—such as men's health campaigns promoting preventive screenings, violence reduction programs, and workplace safety reforms—are essential, especially in high-gap regions. One needs to address men's "double burden" of external and chronic risk. Failing to do so risks continued gender based inequality, with economic ramifications like reduced workforce productivity, families loosing sons, brothers or fathers.

For further work, several extensions are warranted. First, we may extend the analysis and incorporate the bivariate Lee *L* statistic that calculates the spatial association between gender gap and female mortality. Second, cause-specific decompositions (e.g., using Arriaga's method) would quantify contributions from different causes of death. Third, incorporating socioeconomic covariates—such as income inequality, education, and urbanization—via multilevel modeling would clarify drivers, addressing gaps in small-area studies. Fourth, updating to post-2022 data, including COVID-19 impacts, would be important, as the pandemic may have disproportionately affected men and amplified regional disparities. Fourth, comparative analyses with other Latin American countries (e.g., using similar meso-level data) could test if Brazil's patterns are unique or regional. Finally, qualitative studies on gender norms and healthcare utilization could complement these quantitative insights, informing culturally sensitive policies. These avenues would enhance our understanding of mortality dynamics and support evidence-based equity efforts.

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