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Descriptive Finding

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Contents

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Descriptive Finding

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Abstract

BACKGROUND
Cardiovascular disease (CVD) is one of the most serious health issues and the leading cause of death in Brazil, accounting for 30% of all deaths. Previous research shows that CVD mortality rates are not uniformly distributed across Brazil and have been changing over time. There is also previous evidence from other countries that economic development and improvements in the educational level have important effects in reducing CVD mortality.

OBJECTIVE
The goal of this paper is to contribute to this discussion by investigating the relation between CVD mortality and economic development over time and space, measured by gross domestic product (GDP) per capita, in Brazilian micro-regions from 2001 to 2015.

METHODS
We used data from the Mortality Information System (SIM-DATASUS) from 2001 to 2015. GDP data by micro-region were extracted from the Sistema IBGE de Recuperação Automática (SIDRA). Bivariate maps were used to establish the relationship between CVD mortality and GDP per capita.

RESULTS
The results show that GDP per capita increased in all micro-regions between 2001 and 2015. The results also suggest a rapid decline in CVD mortality in the South and Southeast micro-regions and a slower decline in the Central-West region. Meanwhile, the less developed North and Northeast regions showed an increase in CVD mortality over time. This spatial heterogeneity over the examined period appears to be associated with access to proper healthcare and strongly related to socioeconomic factors. In

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addition, males have higher mortality rates than females in approximately 72% of micro-regions.

CONTRIBUTION

This study provides useful clues for policymakers establishing public health planning and effective measures for the prevention of deaths from cardiovascular disease. The reduction of CVD mortality can positively impact GDP growth because it can increase life expectancy and consequently enable people to contribute to the Brazilian economy for a longer time.

1. Introduction

Deaths from cardiovascular diseases (CVD) are increasing and CVD is the leading cause of death worldwide; that is, more people die annually from CVDs than from any other cause (Franco et al. 2011; Lozano et al. 2012; Roth et al. 2015, 2017a, 2017b). In the last twenty-seven years the estimated number of deaths from CVDs increased from approximately 12.0 million in 1990 to 17.8 million in 2017. These numbers represent around 25.6% and 31.8% of all global deaths, respectively (Global Burden of Disease Collaborative Network 2019). In recent years, Lopez and Aidar (2019) have observed a slowdown in the rate of decline in CVD mortality in high-income countries. This pattern and these recent changes are a combination of several factors, such as population growth, aging, education, behavior, climate, access to health services, epidemiologic changes in CVD, and income (GDP) (Timæus 1993; Lopez, Caselli, and Valkonen 1995; Lopez et al. 2006a, 2006b; Vallin and Meslé 2004; Jerrett et al. 2005; Marmot 2010; WHO 2014; Roth et al. 2015; Baptista and Queiroz 2019; Lopez and Aidar 2019).

According to the World Health Organization (WHO) (2016), over three-quarters of deaths from CVD take place in low- and middle-income countries (Franco et al. 2011), like Brazil. While the number of deaths from CVD in Brazil increased from 258,338.97 in 1990 to 388,268.09 in 2017, the percentage has remained fairly stable, 28.89% and 28.78%, respectively (Global Burden of Disease Collaborative Network 2019). However, despite CVD being the main cause of mortality in Brazil (Lotufo 2019), CVD mortality rates are not uniformly distributed within the country (Borges 2017; Baptista, Queiroz, and Rigotti 2018; Baptista and Queiroz 2019). Brazil is marked by important regional disparities resulting from socioeconomic inequality and limited access to health services (Souza et al. 2018).

Due to heterogeneity in both the spatial distribution of deaths from cardiovascular disease and regional socioeconomic conditions in Brazil, the goal of this paper is to

investigate the relationship between CVD mortality and gross domestic product (GDP) per capita in the adult population (over 30 years of age), by sex, in Brazilian micro-regions from 2001 to 2015. This is an attempt to advance the recent study by Baptista and Queiroz (2019), who investigate the spatial pattern of deaths from CVD across small areas in Brazil by performing a spatial analysis of CVD mortality, identifying regions with high levels of mortality, and showing how they have changed over recent periods of time. The results show temporal clockwise change in the concentration of high–high regions (where there is a high level of CVD mortality not only in the region but also in the neighborhood) from the South to the Northeast. Baptista and Queiroz (2019) speculate that these changes may be related to socioeconomic and cultural factors. Following their study, in this paper we aim to investigate associated factors that may explain recent changes in mortality by cardiovascular disease. More specifically, we study the relationship between changes in CVD mortality and a measure of income (GDP) over time and space.

Income, often expressed as gross domestic product (GDP) per capita, is one of the most widely used socioeconomic predictors of mortality/health, and this relationship has been widely discussed in the literature (Preston 1975; Murray and Lopez 1997; Berger and Messer 2002; Mackenbach et al. 2004; Subramanian and Kawachi 2006; James et al. 2012). We introduce an adapted bivariate choropleth map using software R to investigate the temporal and spatial relationship between CVD mortality and GDP per capita in Brazil.

2. Data and methods

2.1 Data source and level of analysis

We use cause-specific mortality from cardiovascular disease from the Tenth Revision of the International Classification of Diseases (ICD-10), Chapter IX, publicly available in the Sistema de Informações sobre Mortalidade (SIM), DATASUS. The data are organized by sex (males and females), age (population over 30 years and in 5-year groups up to 80 years or more), and cause of death, as well as by the geographical micro-region where the deceased resided. In addition, GDP data by micro-region were extracted from the Sistema IBGE de Recuperação Automática (SIDRA), which is also publicly available. We use nominal GDP, not adjusted for inflation, in Brazilian Reais (R$). Unfortunately, the IBGE only reports price indexes for country and various metropolitan areas, and not for municipalities or at the state level.

For purposes of analysis, and in order to adjust any annual fluctuations, we use three 5-year periods: 2001–2005, 2006–2010, and 2011–2015. Population data

organized by age and sex were obtained from the 2010 Census and intercensal estimates from the Brazilian Institute of Geography and Statistics (IBGE). We use standardized death rates for each micro-region, using the Brazilian population in 2010 as the standard.

The units of analysis are the 558 Brazilian micro-regions, as proposed by the IBGE. The micro-regions are statistical constructions aggregated using regional, natural, and socioeconomic similarities, i.e., geographic micro-regions do not constitute political or administrative entities (Cravo, Becker, and Gourlay 2015; Lima and Silveira Neto 2016). One of the advantages of using this type of unit is that their boundaries were constant throughout the research period. Thus, it was possible to monitor and study the 558 areas between 2001 and 2015.

2.2 Bivariate maps

A univariate choropleth map uses colors that portray the spatial variation of a single attribute in the geographic region under study. Fertility rate by county, crime rate by state, and aging rate by country are some examples. Bivariate choropleth maps follow the same concept but display two variables simultaneously (Carstensen 1986). In fact, bivariate maps go further in that they indicate estimates of the degree or spatial pattern of cross-correlation between variables, something that to our knowledge has not yet been explored in demographic studies.

We introduce an adapted bivariate choropleth map based on Grossenbacher and Zehr's tutorial (2019) in R software to evaluate the degree of relationship between mortality by cardiovascular disease and GDP per capita at the micro-region level. To match the nine different colors with appropriate classes we calculate 1/3-quantiles for both variables. The micro-regions are then put into the appropriate class corresponding to their average CVD mortality and GDP per capita.

3. Results

Figures 1 (males) and 2 (females) show the relationship between CVD mortality and GDP per capita in the three 5-year periods studied, by micro-region, through bivariate maps.

The overall results show that GDP per capita increased in all micro-regions between 2001 and 2015. The results also suggest a rapid decline in CVD mortality in the South and Southeast micro-regions and a slower decline in the Central-West region. Meanwhile, the less developed North and Northeast regions observed an increase in

CVD mortality overtime (see Figures A-1 and B-1 in the supplementary material). This spatial heterogeneity over the period appears to be associated with access to proper healthcare and strongly related to socioeconomic factors (Mansur and Favarato 2016; Baptista, Queiroz, and Rigotti 2018; Lotufo 2019). In addition, males have higher mortality rates than females in approximately 72% of micro-regions.

Figure 1: CVD mortality rates vs. GDP per capita, males, micro-regions, Brazil. Five-year periods 2001–2005 (left), 2006–2010 (middle), and 2011–2015 (right)

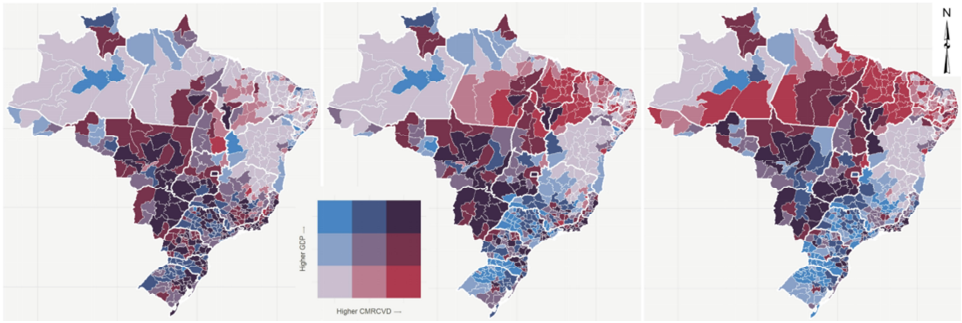
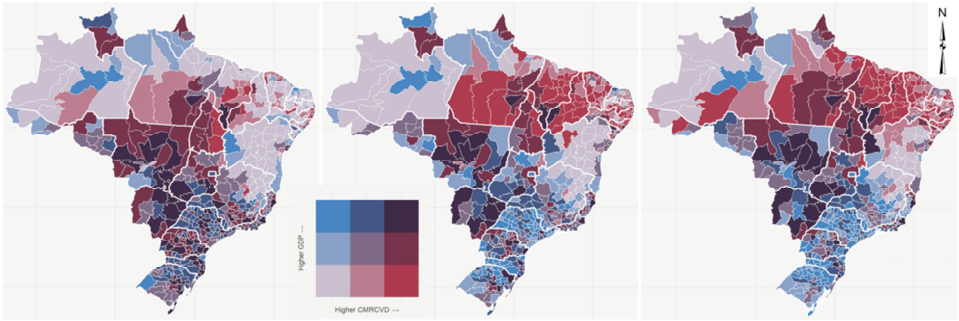


Figure 2: CVD mortality rates vs. GDP per capita, females, micro-regions, Brazil. Five-year periods 2001–2005 (left), 2006–2010 (middle), and 2011–2015 (right)



We observed that, on the one hand, most of the micro-regions of the North and Northeast regions remained in the same low or medium quantile of GDP per capita over

the period. On the other hand, analysis of the period 2001–2015 found an increase in the crude mortality rate from cardiovascular disease (CMRCVD). As these are less developed regions, the increase in CVD mortality rates might be related to the population's increased life expectancy and an increased prevalence of cardiovascular risk factors such as educational level, health conditions, institutional factors, the environment, and the socioeconomic situation to which the population is exposed (Roth et al. 2015; Borges 2017; França et al. 2017; Lotufo 2019), as well as improvements in death registration and vital statistics (Mathers et al. 2005; França et al. 2008; Luy 2010; Queiroz et al. 2017; Schmertmann and Gonzaga 2018).

In the Central-West region the relationship between CVD and GDP per capita is clearer. The region is an important and increasingly mechanized agricultural frontier, and a significant contributer to the country's GDP. The CMRCVD is high in the first 5-year period but shows signs of decline (albeit slower than in the South and Southeast regions) in the most recent period. This decrease in rates is stronger and more noticeable from the first to the second 5-year period, for both sexes. In a few micro-regions the rates increase between the second and third 5-year period, but there is no return to the high rates of the initial period. The Central-West region has undergone profound changes in recent decades because of agricultural expansion into the interior (Hosono 2019). This development has brought epidemiological changes, changes in the population age structure, and improvements in access to and quality of health services and in the quality of vital statistics, all of which may help to explain the relationship studied.

In the Southeast region, where the three largest economies are located, there is more variation in relative income level and mortality. Minas Gerais, for example, has a low relative GDP per capita in the North and Northeast regions of the state, as opposed to a medium/high relative GDP per capita in the other regions. The region saw a decline in CMRCVD over the period, and this reduction tended to occur first among women (Brant et al. 2017). We speculate that the fall in CMRCVD in more developed regions of the country may be explained by the control of risk factors, improved education and health conditions, early diagnosis of cardiovascular risk, and the search for a better quality of life (Ribeiro, Minardi Mitre Cotta, and Rocha Ribeiro 2012; Rasella et al. 2014; Lotufo 2019).

In the southern region, most of the micro-regions of the states of Santa Catarina (SC) and Rio Grande do Sul (RS) had a high relative GDP per capita between 2001 and 2015. In the state of Paraná (PR), relative GDP per capita ranged from medium to high. Moreover, in RS and SC the CMRCVD showed a faster decline than in PR and, again, the reduction was observed first for females. The South region, together with the Southeast region, are the most developed regions of the country. Therefore, in addition to the previous considerations regarding the relationship between CVD and GDP per

capita, we can add that the decline in risk factors associated with policies such as tobacco control and better preventive care of high blood pressure (França et al. 2017; Brant et al. 2017), as well as the quality of hospital care, play an important role in the declining trend, and that there are large regional differences in quality (Ribeiro et al. 2016; Brant et al. 2017) should also be considered.

In summary, we would characterize Figures 1 and 2 as showing a shift from light gray (low relative GDP per capita and low CMRCVD) to red (low relative GDP per capita and high CMRCVD) in the North and Northeast regions, and a shift from purple (high relative GDP per capita and high CMRCVD) to blue (high relative GDP per capita and low CMRCVD) over time in the South and Southeast regions.

4. Discussion

Mortality by cardiovascular diseases is related to population age structure, prevalence of risk factors, health conditions, institutional factors, the environment, and the socioeconomic situation to which the population is exposed (Roth et al. 2015; Ribeiro et al. 2016; Lopez and Adair 2019). In Brazil, CVD mortality presents important regional variation and is strongly related to socioeconomic factors (Lotufo 2000; Godoy et al. 2007; Guimarães et al. 2015; Mansur and Favarato 2016; Brant et al. 2017; Baptista and Queiroz 2019). One of the most widely used socioeconomic predictors of mortality/health is GDP (Preston 1975; Murray and Lopez 1997; Berger and Messer 2002; Mackenbach et al. 2004; Subramanian and Kawachi 2006; James et al. 2012).

The aim of this paper is not to investigate the causal relationship between CVD mortality and GDP per capita. Our goal is to, raise and examine some research questions regarding the association between socioeconomic factors, measured by GDP per capita, and CVD mortality. Gu et al. (2013), studying Southeastern Asia, show that higher GDP per capita is associated with lower mortality rates. They find that the relationship between CVD and GDP tends to reduce once a certain level of GDP is reached. Brazil's economic development has undergone many changes in recent years. Regions in the poorest areas of the country show impressive improvement in income and educational levels (Fontes, Simões, and Hermeto Camilo De Oliveira 2010; Haddad 2018). There is a process of convergence, but important inequalities persist. Due to the rapid change in mortality profile, we argue that investigating the association between income level and CVD mortality contributes to understanding the mortality dynamic in Brazil. In addition, Lotufo (2019) shows that the reduction in CVD mortality is slowing down. A recent study by Lopez and Adair (2019) finds similar trends for more developed economies.

There is also the important question of reverse causality. Suhrcke and Urban (2010) show that increasing CVD morbidity can affect economic growth because it limits productivity and labor force participation. In this paper we do not have evidence to suggest the direction of causality. Our results indicate an association between GDP per capita and CVD mortality across regions in Brazil. Through bivariate maps, we show that over the examined period there is a decline in CVD mortality in the South and Southeast micro-regions of Brazil, significantly the most developed regions of the country. To a lesser extent, the Central-West region also saw a decrease in mortality rates from cardiovascular disease. On the other hand, CVD mortality increased in the states with poor socioeconomic conditions (the North and Northeast) at the same time as there was an increase in public health programs aimed at controlling chronic diseases and individual behaviors (Ribeiro, Minardi Mitre Cotta, and Rocha Ribeiro 2012; França et al. 2017). GDP per capita might be working as a proxy for inequalities in the social environment, behavioral risk factors such as smoking, obesity, physical inactivity, disease prevalence, and healthcare access and treatment.

The inverse relationship between mortality and GDP per capita – increases in GDP related to a decline in mortality – is parallel to that observed in the relationship between CVD mortality and education in other countries. As the educational level rises the more educated individuals have more resources to avoid disease, and their survival increases. In Brazil, public health measures providing information and additional resources to more vulnerable populations had an important impact on reducing CVD mortality among the less wealthy population. However, CVD mortality decline is slower in the less developed areas of the country, indicating that income level plays an important role in this disease (Lotufo et al. 2013; Ribeiro et al. 2016; França et al. 2017). In addition, the slowdown in the mortality decline suggests that alternative public health measures should be put in place.

Our results are in line with others that focus on states or major regions of Brazil, although we provide results for small regions (micro-regions). Souza et al. (2001) analyze CVD deaths in the five Brazilian geographic regions by age and sex. Although the period of analysis (1979–1996) is different from that covered in this study, they show that there was an increase in CVD mortality in the less developed regions (Central-West, North, and Northeast) and a decrease in the southeastern and southern regions. Godoy et al. (2007) use socioeconomic variables (education and income) to analyze CVD mortality indicators in São José do Rio Preto (São Paulo,Brazil). They point out that the mortality rate of the lowest socioeconomic census tracts was 40% higher than in those with the best socioeconomic conditions. Lotufo et al. (2013) show that in the city of Sao Paulo, CVD mortality declines for residents in wealthier areas. Ribeiro, Minardi Mitre Cotta and Rocha Ribeiro (2012) examine the influence of socioeconomic status and regional variation in the epidemiology of CVD in Brazil.

They note that the country is among those in which the increase of CVD mortality attributable to population growth and aging has been offset by a reduction in age-specific rates of death. They also find that CVD mortality does not have a consistent geographic pattern, although some states in the Northeast have high rates, and that the decline in age-standardization has been higher among women than among men. Borges (2017) points out that changes in CVD mortality have benefited older adults in all regions and have had an important impact in reducing overall mortality levels for women, especially in southern regions of the country. Brant et al. (2017) show that there was a reduction in CMRCVD between 1990 and 2015, although not uniformly across all Brazilian states. The decline was higher in the southeastern and southern regions of the country and in the Federal District, while the lowest reductions occurred in the northern and northeastern regions where the socioeconomic conditions are the worst. Baptista, Queiroz, and Rigotti (2018) analyze the recent evolution of mortality due to cardiovascular disease and decompose the effects of changes in the levels of mortality rates and age structure of the population. They note an increased concentration of high mortality rates from this disease in the Northeast. Finally, Baptista and Queiroz (2019) evaluate the spatial patterns of deaths from CVD in Brazilian micro-regions between 1996 and 2015. They find a decrease in high–high spatial clusters in the Southeast and South regions. Meanwhile, the micro-regions of the Central-West, North, and Northeast regions in general have seen an increase in mortality rates over the years.

We argue that this study provides useful clues for policymakers establishing effective public health planning and measures for the prevention of deaths from cardiovascular disease. The reduction of CVD mortality can positively impact GDP growth because increasing life expectancy enables people to contribute to the economy of the country and its regions for longer. Some important research issues raised by this paper should be considered in future studies. The relationship between CVD and income is important, and some studies show a reduction in the decline in CVD mortality in high-income countries (Lopez and Aidar 2019). In Brazil, regions with higher GDP show a decline in CVD mortality rates, but will this be consistent over time, or will Brazil follow the richest countries? How are health measures dealing with the aging process and changes in the behavior of the population? These questions need to be on the research agenda.

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Supplementary material

Figure A-1: CVD mortality rates vs. GDP per capita vs. population, males, micro-regions, Brazil. Five-year periods 2001–2005 (left), 2006–2010 (middle), and 2011–2015 (right)

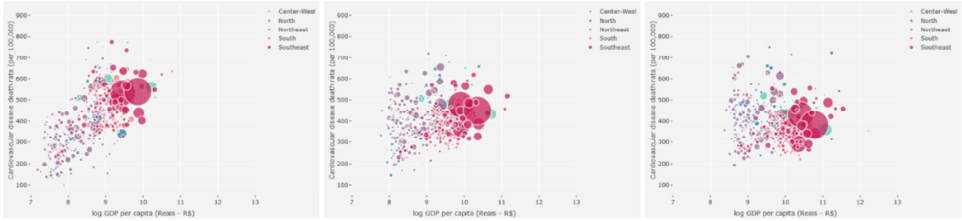

Figure B-1: CVD mortality rates vs. GDP per capita vs. population, females, micro-regions, Brazil Five-year periods 2001–2005 (left), 2006–2010 (middle), and 2011–2015 (right)