The evolution of causes of deaths in relation to economic development death: study for small areas in Brazil, 1991-2010[1]

Emerson A. Baptista
Asian Demographic Research Institute
emersonaug@gmail.com

Bernardo Lanza Queiroz
Universidade Federal de Minas Gerais
lanza@cedeplar.ufmg.br

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Abstract

Background

There are signs of convergence in infant mortality among the regions of Brazil, as infectious diseases have reduced their number of deaths, but there are still great differentials in life expectancy at birth and adult mortality in all Brazilian regions. Recent studies investigate the patterns of causes of death overtime and show how the changes in the patterns impact the evolution of life expectancy at birth and the mortality differentials observed in the country.

Objectives

The main objective of the paper is to try to establish a relationship between mortality by causes of death and economic development, measured by gross domestic product (GDP) per capita, in the adult population (over 30 years of age), by sex, in Brazilian micro-regions from 1991 to 2010

Data and Methods

We use data from the System Data Mortality Information (SIM-DATASUS) from 1991 to 2010. We use GDP data by micro-region as a measure of economic development. Data are public available from the *Sistema IBGE de Recuperação Automática (SIDRA)*. We introduce an adapted bivariate choropleth map based on Grossenbacher and Zehr's tutorial (2019) in R to evaluate the degree of relation between mortality by cardiovascular disease and GDP per capita at the micro-regions level.

Contributions

This study provides useful clues for policy makers in establishing effective measures for the prevention and public health planning of deaths by external and non-communicable causes of deaths. The dynamics of mortality by cause and its relation to economic conditions are important to better understand future trends in economic development. As mortality declines, one can expect positive impact on economic growth for increase in life expectancy and better health might increase worker´s productivity.

Introduction

In the last decades, Latin America has experienced an accelerated decline in infant, child and adult mortality. The median gain in life expectancy at birth between 1950 and 2010 was about 15 years, a much faster process than in developed countries. In 1950, life expectancy at birth in the region was 51 years, reaching 67 years in 1990 and more than 70 years in 2010. However, rates observed around 2000 in several Latin American countries were like observed rates in the US and Canada. in the 1950s (Palloni and Pinto, 2011), thus showing that there is still room for improvement in terms of life expectancy in the region. In addition, there is a wide variation in levels of mortality and life expectancy among and within the countries of Latin America (Alvarez, Aburto and Canudas-Romo, 2019; Gonzaga, Queiroz and Lima, 2018).

Brazil followed a similar path. There are signs of convergence in infant mortality among the regions of Brazil, as infectious diseases have reduced their number of deaths, but there are still great differentials in life expectancy at birth and adult mortality in all Brazilian regions (Castro and Simões, 2009; Queiroz, et.al, 2018). Recent studies (França, et al, 2017; Borges, 2017) analyze the states of the federation (UFs) or large regions and show how the changes in the pattern of causes of death impact the evolution of life expectancy at birth and the mortality differential observed in the country. However, the Brazilian regions are also marked by large inequalities and the understanding of this dynamic in smaller areas is fundamental for demographic and public health studies.

The determinants of mortality decline can be aggregated in two large groups, macro and micro ones. Micro determinants involve the characteristics of individuals and their health behavior. In addition, micro factors can influence macro level factors because they are directed related to the composition of the population in each area, such as the age composition of the population and the educational distribution of the population in each area. Changes in mortality levels across regions can be explained by macro level factors - health services, regional trends in health factors, institutional factors – and micro level factors – individual behavior, income level, educational level, and the combination of macro and micro factors can feedback each other (Soares, 2007; Cutler, Deaton and Lleras-Muney, 2006).

Due to the heterogeneity in the spatial distribution of deaths by causes in Brazil - neoplasms, cardiovascular diseases, external causes, respiratory diseases and infectious diseases - , as well as socioeconomic conditions in Brazil, the goal of this paper is to investigate the relationship between mortality by causes of death 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. We focus on these specific causes for they represent the majority of deaths observed in the country and have an interesting variation over the life cycle. That is, we investigate deaths that are concentrated at younger ages, prime-age adults and older ages.

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; Stronks et al. 1997; Ecob and Smith 1999; Berger and Messer 2002; Mackenbach et al. 2004; Subramanian and Kawachi 2006; James et al. 2012). We introduce an adapted bivariate choropleth map and bubble charts using software R to investigate temporal and spatial relationship between mortality by cause of death and GDP per capita in the country.

Literature Review [2]

Followed by a rapid mortality transition from high to low levels, Brazil also experienced a rapid epidemiological transition (Borges, 2017). However, the latter process did not follow the same pattern as that verified in most industrialized countries and other Latin American countries, such as Chile, Cuba, and Costa Rica (Prata, 1992; Schramm et al., 2004, França et al. 2017, Borges, 2017). Empirical evidence shows that there is overlap in transitional states of health, the persistence of infectious diseases (eg dengue, cholera, malaria, etc.) in parallel with the increase mortality rates by chronic and degenerative diseases. Calazans and Queiroz (2018) find that, using multiple decrements life tables, that cardiovascular diseases and external causes of deaths have the largest impact on life expectancy in Brazil and that differences in causes of deaths play an important role in gender differences in mortality levels. Thus, there is no linear pathway across all stages of the epidemiological transition, leaving it in the counter-transition state (Schramm et al., 2004; Frenk et al., 1991, França, et al., 2017; Borges, 2017). In addition, the two morbidity-mortality groups are also at high levels, characterizing themselves as a long-term transition process. Also, there are contrasting epidemiological situations in different regions of the country, also creating a scenario of epidemiological polarization (Schramm et al., 2004, Frenk et al., 1991, França, et.al, 2017 and Borges, 2017).

[2] This section will present a up-to-date review of the literature and discuss in detail the relevance of the paper and analysis for the case of Brazil.

We argue that large and persistent levels of income and regional inequality play an important role in observed differences in mortality levels across socioeconomic groups and regions of a country (Fenelon, 2013; Wilmoth et. Al, 2011, Bafuri, et.al, 2012). Preston (1976) showed that most gains in life expectancy were independent from income level. But, a series of studies indicate the importance of economic conditions on the reduction of mortality levels in more recent periods. Pritchet & Summers (1996) estimated that an 10% increase in income level is related to a 2% decline in infant mortality. They argue that public health measures and other interventions played an important role, but income level has its own effect and affect other variables. Using the Preston Curve – relation between life expectancy and income level – Mackenback and Looman (2013) argue that income level plays a primary role in the trends in mortality after 1960 for developed countries.

In the case of Brazil, Baptista, Queiroz and Rigotti (2018) analyze the recent evolution of mortality due to cardiovascular diseases and decompose the effects of changes in 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. Along the same lines, Pinheiro and Queiroz (in press) estimate mortality rates for motorcycle accidents in small areas and observe a concentration in the frontier areas of the country and the interior of less developed states. Schmmertman and Gonzaga (2018) proposes a Bayesian method to estimate data quality and mortality rates for small areas in Brazil in 2010. The methodology allows to properly evaluate the data for small areas and obtain more robust estimates and it is the base of the methodological approach we use in this paper. Queiroz et al. (2018) analyze the differential of adult mortality between 1980 and 2010 in Brazil and observe, as for other countries, how social and economic factors influence trends in time and space. They show that an increasing percentage in the share of young adult population is related to an increase in 45q15 for both males and females. They also find that, for females, decrease in unemployment rates from 1980/1991 to 2000/2010 is related to an increase in the 45q15. This is an unexpected result and more analyses need to be performed in order to understand this association. Gini Index, a measure of income inequality, has also an impact on the observed changes in 45q15, but only among males. More intriguing, the relationship has change signal during the period of analysis, indicating that improvements in income distribution (decline in Gini) are associated with more deaths between ages 15 to 60 years

Queiroz, et.al (2019) find that the quality of mortality data (completeness of registration and quality of causes of death information) in Brazil and regions is improving over time, and a large part of the country shows almost complete coverage of death counts. The improvement is mostly explained by public investments in collection health data. Sex differentials in mortality remained high over the period of analysis due to the increase in external causes of deaths especially among males. This increase also explains the high concentration of male adult mortality in some areas of the country. More important, they observed a convergence process for causes of deaths across regions in the country over time. They point some interesting and important findings: a) increase in the mortality by violence in the northeast part of the country and middle-size towns; b) change in the concentration of mortality due to cardiovascular diseases from the South to the Northeast and c) concentration of high mortality levels for neoplasm in the southeast. We move from this finding and try to show a relation between economic development, measured by income level, and changes in the mortality by causes of deaths across regions in Brazil.

DATA & METHODS

Data source and level of analysis

We make extensive use of the Ministry of Health database, DATASUS (http://www2.datasus.gov.br). The database provides information on deaths, causes of deaths, by age and sex at the municipality level. The data are available since 1979, but we use information from 1990 to 2010. 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, provincial and state level, 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 (1980, 1991, 2000 and 2010) and from IBGE estimates for periods after the census.

The original data is available at the municipality level. The main limitation in using city level data in Brazil is that the number and composition of cities change over time. In 1980, there were 3974 municipalities and in 2010 there were 5565. To avoid problems using this information, we aggregated municipalities by comparable small areas, using the IBGE definition of comparable mesoregions. The mesoregions serve only for statistical purpose; therefore, they do not represent a political or administrative entity.

The main advantage of working with these geographical areas is that they have not changed their boundaries over the period of analysis and they are areas with regional and socioeconomic similarities. Mesoregions are stable and comparable over the period of analysis. By doing this, we are able to follow and study over 500 small areas in Brazil from 1990 to 2016.

Ministry of Health data, Datasus, is publicly available. Historically, states of the North and Northeast observed lower coverage and worse quality of death declarations in relation to the states of the Southeast and South (Queiroz, et.al 2017, Lima and Queiroz, 2014, Agostinho and Queiroz, 2010). However, since the 2000s, there has been an impressive improvement in both conditions (Queiroz, et.al 2017, Lima and Queiroz, 2014, Agostinho and Queiroz, 2010). The improved quality of mortality information in the North / Northeast has radically altered the trends, mainly due to noncommunicable diseases. We are using data from 1996 to 2016. Several articles argue and show that the quality of the information has improved since it allows an adequate comparison between the regions (Guimarães, et al., 2015, Borges, 2017; França, et.al, 2017; Ross, 2018)

In addition, GDP data by micro-region were extracted from the Sistema IBGE de Recuperação Automática (SIDRA) and are also publicly available. The GDP data for each year of the series are based on the year 2010 and are given at current prices in Reais (R$).

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, aging rate by country are some examples. Bivariate choropleth maps follow the same concept, except for displaying *two variables* simultaneously. In fact, bivariate maps go further, that is, allows to estimate the degree or spatial pattern of cross-correlation between variables.

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

Preliminary Results

Figure 1 shows the results for external causes of deaths from 1991 to 2010. The overall results show that GDP per capita has increased in all micro-regions during the period of analysis. The results indicate a very fast increase in external causes of deaths in the Northeast part of the country and new frontier areas, such as in the Center-West. In 1991, highest levels of external causes of deaths were concentrated in Rio de Janeiro, São Paulo and around Brasilia. We also observed very high mortality rates by external causes in frontier areas of the Amazon and Brazilian Cerrado. In 2010, we observed an interiorization of the mortality due to external causes of deaths and an increased in the mortality by this cause in almost all coastal cities of the northeast part of the country. There is also a rapid increase in the coastal areas of the country from Rio de Janeiro to the most northern capitals of the coastal. São Paulo, on the other side, has shown significative signs of decline in mortality by external causes during the period of analysis. Ingram, et.al (2017) show strong evidence that the increase of violence in one city tend to increase violence in the cities around following a diffusion process. They also show that inequality levels have mixed results leading to higher violence in some areas of the North and to lower levels of homicides in the southern parts of the country.

Figure 2 shows the results for males and the relation between economic development and mortality rates by cardiovascular diseases. Previous studies, show that mortality for cardiovascular diseases were declining in the country over 20 years period, for the larger 5 regions, and were related to improvements in social and economic variables (Curioni, et.al, 2009). They also suggest that the magnitude of the decline varies with economic level. The main limitation, compared to our study, is that they analyze only 5 regions loosing a lot of variability in the study. We find for males, in the Center-West, South and South-East (except for the northern region of the state of Minas Gerais), we found a decline in mortality by over time. In the North and, specially, across the Northeast regions, and the northern region of the state of Minas Gerais, there was an increase mortality over the years. The results suggest a rapid decline in CVD mortality in the South and Southeast micro-regions and a slower decline in the Center-West region. Meanwhile, the North and Northeast regions, less developed areas of the country, observed an increase in CVD mortality overtime. This spatial heterogeneity over the period seems to be associated with access to proper healthcare and strongly related to

socioeconomic factors (Mansur and Favarato 2016; Baptista et al. 2018; Lotufo 2019). One important result is that even though mortality rates for most of regions are decline, the absolute number of deaths due do CVD are increasing because of rapid changes in population age structure.

Figure 3 and Figure 4 show the relation between economic development and mortality rates by neoplasm and respiratory diseases. We observed that they are more concentrated in the more developed parts of the country – South and Southeast. Those regions are in later stages of the epidemiological and demographic transitions compared to the other parts of the country (Borges, 2017; França, et.al. 2017). Carvalho and Paes (2019) find a strong relation between older population age structure and better socioeconomic indicators and mortality due to breast cancer in the northeast of the country. They argued that the variation in mortality is related to variation in incidence and the incidence is affected by a series of social and economic factors. Barbosa, et.al (2016) investigate cancer mortality at the municipal level and find that mortality levels are higher in more developed regions measured by income level and life expectancy. One limitation of their study is that they do not perform any adjustment in data quality.

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Figure 1: External Causes of Deaths mortality rates vs GDP per capita, males, micro-regions, Brazil – 1991 (left), 2000 (middle) and 2010 (right)

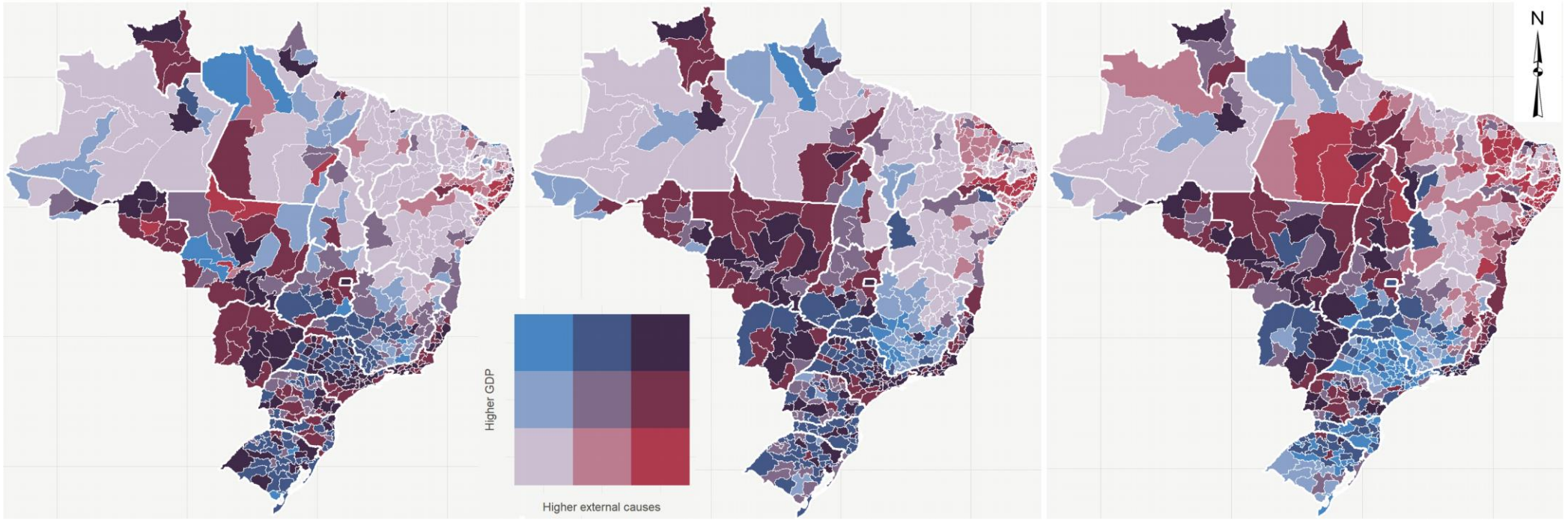

Figure 2: Cardiovascular Causes of Deaths mortality rates vs GDP per capita, males, micro-regions, Brazil – 1991 (left), 2000 (middle) and 2010 (right)

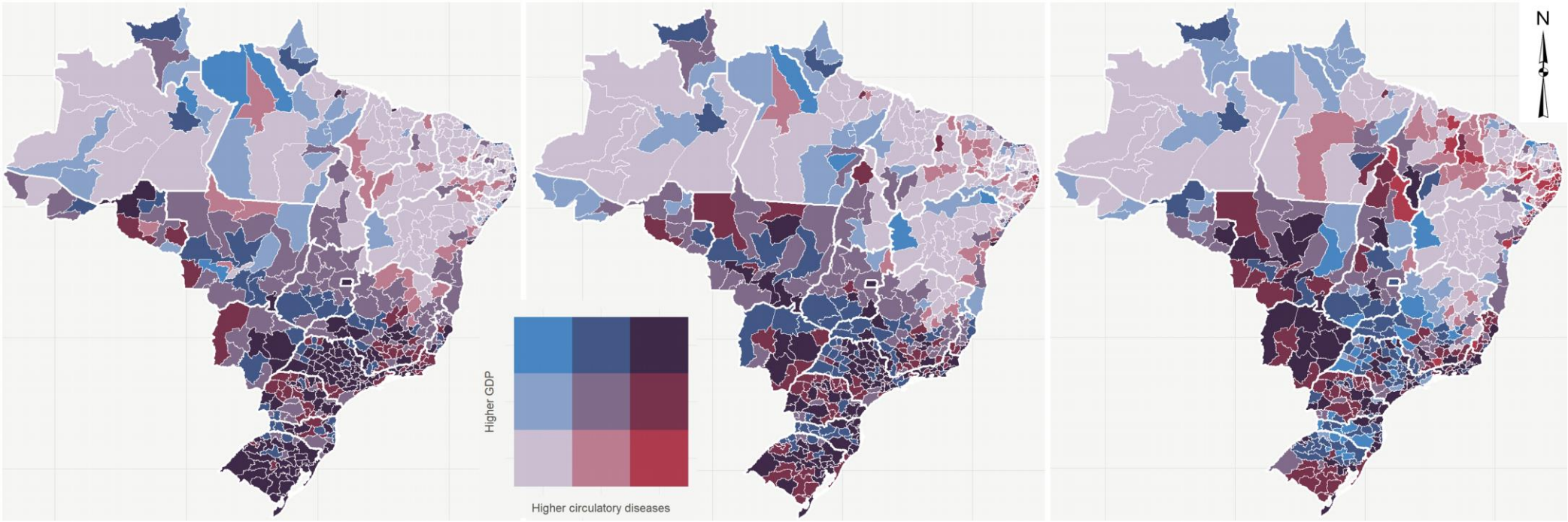

Figure 3: Respiratory Causes of Deaths mortality rates vs GDP per capita, males, micro-regions, Brazil – 1991 (left), 2000 (middle) and 2010 (right)

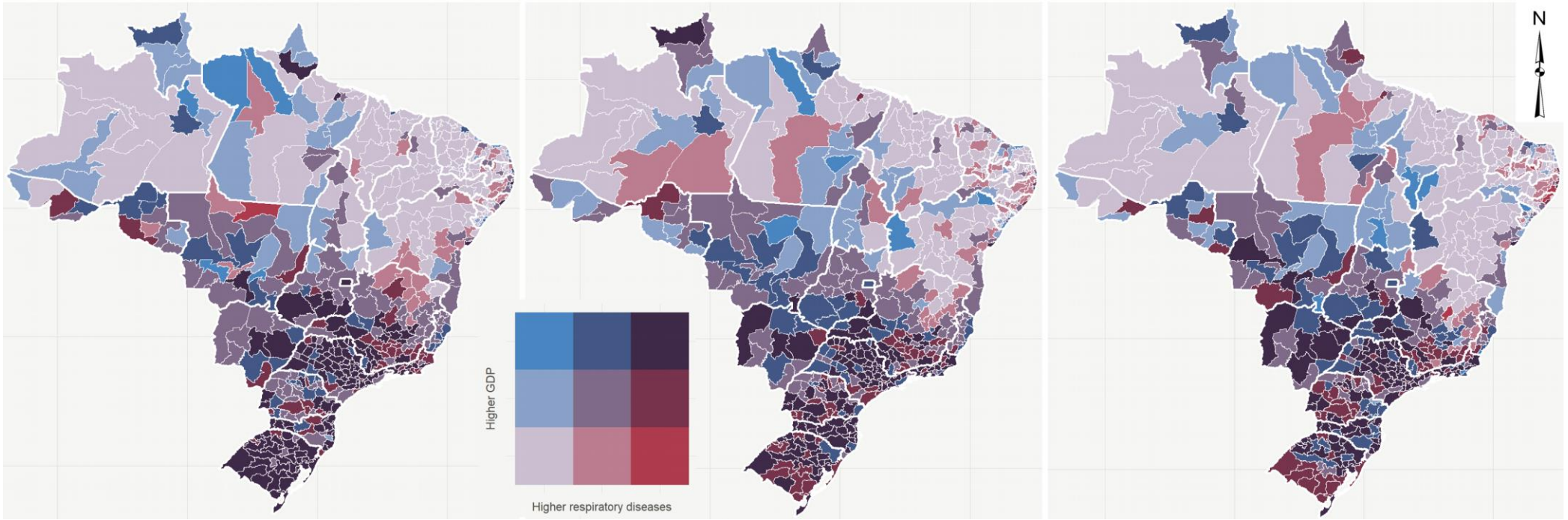

Figure 4: Neoplams Causes of Deaths mortality rates vs GDP per capita, males, micro-regions, Brazil – 1991 (left), 2000 (middle) and 2010 (right)