THE EFFECT OF PUBLIC SPENDING ON DEATHS FROM NONCOMMUNICABLE DISEASES

Wallace Lobato Siqueira and Adriano Mendonça Souza. The effect of public spending on deaths from noncommunicable diseases. Revista Ciência Dinâmica, vol. 14, núm.2, 2023. Faculdade Dinâmica do Vale do Piranga.

CIÊNCIA DINÂMICA - Electronic Scientific Journal
FACULDADE DINÂMICA DO VALE DO PIRANGA

24th Edition 2023 | Year XIV - nº 2 | ISSN - 2176- 6509

DOI: 10.4322/2176-6509.2023.009

2nd semester 2023

FACULDADE Dinâmica FORMANDO PESSOAS

The effect of public spending on deaths from noncommunicable diseases

The effects of public spending on NCDs deaths

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Abstract

This study aimed to analyze the spatial autocorrelation of deaths caused by noncommunicable diseases (NCDs) and the effect of public spending on health and education in addressing these conditions in Brazil from 2013 to 2019. To achieve this objective, data from the Department of Informatics of the Brazilian National Health System (DATASUS) and the Brazilian Public Sector Accounting and Tax Information System (SICONFI) were used. Employing exploratory spatial data analysis (ESDA) and spatial panel data regression, the study revealed a positive relationship between public spending on health and education and the mortality rates of NCDs. Additionally, spatial autocorrelation was identified, suggesting that NCD-related deaths in one municipality can influence rates in neighboring municipalities. This finding emphasizes the significance of considering spatial interactions in the formulation of health policies.

Keywords*: NCDs, Government spending on health and education, ESDA, Spatial Panel Data.*

Resumo

Este estudo analisou a autocorrelação espacial dos óbitos por doenças crônicas não transmissíveis (DCNT) e os efeitos dos investimentos públicos em saúde e educação nessas enfermidades no Brasil entre 2013 e 2019. Para isso, utilizou-se dados do DataSUS e do Sistema de Informações Contábeis e Fiscais do Setor Público (Siconfi), empregando análise exploratória de dados espaciais e regressão de um painel de dados espaciais. Os resultados destacam uma relação positiva entre gastos públicos em saúde/educação e a mortalidade por DCNT. Também foi identificada autocorrelação espacial, indicando que óbitos por DCNT em um município podem influenciar as taxas em cidades vizinhas. Esse efeito enfatiza a importância de considerar interações espaciais na elaboração de políticas de saúde.

Palavras-chave: *DCNT, Gastos Governamentais em Saúde e Educação, Análise Exploratória de Dados Espaciais, Dados em Painel Espacial.*

INTRODUCTION

The relationship between health and the economy is inseparable since health has a direct impact on individual productivity, absenteeism from work, and public spending. In addition, healthy eating and regular exercise play a fundamental role in promoting a better quality of life (CUNHA; HECKMAN; SCHENNACH, 2010). In Brazil, various nutritional initiatives have been implemented at different levels of government, ranging from prenatal and postnatal nutrition to actions aimed at the school population, workers, and the elderly. In this context, the Family Health Program was also created, to prevent and monitor diseases (SANTOS *et al.* 2015).

Even so, 54.7% of deaths in 2019 in Brazil were due to preventable causes, in the population aged between 30 and 69, caused by noncommunicable diseases (NCDs), related to poor diet - mainly due to the consumption of hypercaloric and ultra-processed products, smoking, excessive alcohol intake, and a sedentary lifestyle (WHO, 2022).

NCDs are the group of diseases with the highest incidence in the world. In 2019, 74% of deaths recorded on the globally were from this group, while in Brazil this result was 76%. The most vulnerable groups in society are the most affected by this problem, as they have low access to income and schooling, as well as greater exposure to risk factors, such as problems with access to information and/or health services (BAKER *et al.* 2020; WHO, 2022).

Malta *et al*. (2017) found that people with NCDs used the Unified Health System (SUS) twice as much as those without the disease. Baker *et al.* (2020) pointed out that there has been a high expansion in the consumption of ultra-processed foods in developed countries, especially affecting the poor and urban populations. Meanwhile, Becker and Siqueira (2022) found that regulations restricting the sale of high-calorie, low-nutrition foods in school canteens prevented one death per 100,000 inhabitants in the 5-14 age group and two in the 15-19 age group.

In this context, this study aims to analyze the effects of public spending on health and education on the incidence of deaths from preventable causes. To this end, was used the exploratory spatial data analysis (ESDA) methodology and the estimation of a panel of spatial data by fixed effects with data from the Department of Informatics of the Brazilian National Health System (DATASUS), specifically, from the Mortality Information System (SIM), the Outpatient Information System (SIA) and the Hospital Information System (SIH). Data were also utilized data from the Brazilian Public Sector Accounting and Tax Information System

(SICONFI) and the Brazilian Institute of Geography and Statistics (IBGE) between 2013 and 2019.

This study is justified by the relevance of understanding how public spending can influence mortality from preventable causes, providing valuable information for the development of effective public policies. This will allow for the strategic allocation of resources, providing important evidence to support policymakers' decisions and directing investments to priority regions and areas. Health promotion consists of preventing and controlling NCDs and tackling public health challenges, seeking to continuously improve the well-being of Brazilian society.

This study is structured in five sections, the first of which comprises this introduction; section 2 includes the empirical framework; section 3 discusses the methods adopted; section 4 presents and analyzes the results obtained; and finally, the fifth section concludes with the results obtained.

EMPIRICAL REFERENCE

Promoting quality of life and preventing NCDs has been a central concern of the Brazilian Ministry of Health, which has adopted measures to care for the population. Among these measures, notably, the creation of laws aimed at improving the nutritional quality of school meals and the development of the Dietary Guidelines for the Brazilian population (2015), which offers guidance on the choice of foods and combinations for efficient nutrient absorption.

Becker and Siqueira (2022) conducted an impact evaluation of state regulations on hypercaloric and sugary foods on deaths from NCDs in Brazil, between 2003 and 2018, within the school-age population, using the difference-in-differences method. The results indicate that restricting the sale of these foods in school canteens contributed to a reduction of one death in the 5-14 age group and two in the 15-19 age group per 100,000 inhabitants. Although these results modest, they are significant and relevant, given that the effects of health policies tend to be long-term.

Malta *et al*. (2016) detailed the actions of the Strategic Action Plan for Tackling NCDs up to 2015 in Brazil. The plan aimed to reduce the incidence of cardiovascular diseases, neoplasms, chronic respiratory diseases, and diabetes by 2022, through policies that included restrictions on high-calorie foods, incentives to consume fresh products, and agreements with food companies to reduce salt content. Despite these actions, there was an increase in the prevalence of overweight, obesity, and diabetes in the country during this period, highlighting the complexity of the problem.

In 2017, another study underscored the relationship between NCDs and access to health services in Brazil. Using data from the 2013 National Survey of Health (PNS), the analysis showed that individuals with NCDs sought health services twice as often as those without such conditions, especially among those with lower levels of education (MALTA *et al*., 2017). Malta *et al*. (2017) emphasized the importance of implementing inclusive policies and offering differentiated care to the most vulnerable populations. When analyzing the trend in mortality from NCDs between 2000 and 2013, demonstrated a reduction in the average premature mortality rate of 2.5% per year (MALTA *et al*., 2019).

This decrease is a step towards meeting the targets set by the United Nations for reducing premature deaths, highlighting the relevance of health policies in achieving the Sustainable Development Goals. Even so, 72.6% of deaths recorded in 2013 were attributable to preventable causes, i.e., some form of NCDs, of which 29.7% were due to cardiovascular diseases, 16.8% to neoplasms, 5.9% to chronic respiratory diseases, and 5.1% to diabetes (MALTA *et al*., 2019).

Pereira *et al*. (2017) investigated risk factors for NCDs among adolescents from a sample of students aged 10 to 17 in the Health and Prevention at School program (SPE) in the municipality of Imperatriz, MA, Brazil, between 2014 and 2015, using questionnaires and anthropometric assessments using chi-square (χ^2) statistics. The results showed that 64% of the students sampled consumed sweets, 47% soft drinks, and 28-51% high-calorie foods. It was also observed that around 27% of the students did not exercise, 13% were identified as overweight or obese, and 9% as malnourished. Poor diet and a sedentary lifestyle are associated with overweight, obesity, and malnutrition, highlighting the need for interventions aimed at this age group.

Analyzing the food environment of schools in 124 Brazilian municipalities, using the Study of Cardiovascular Risks in Adolescents (ERICA) between 2013 and 2014 employing the χ^2 statistic, Carmo *et al*. (2018) reported that only 8% of private schools offered school meals, while in the public school system, the offer was universal (98.15%); it was observed that 35.7% of public schools offered for sale sweets and soft drinks (34.9%) and fried foods (40.6%), while in private schools, these figures were 79.7%, 75.2%, and 93.2%, respectively. It was also found that 25% of the private school sample had displayed advertisements for high calorie foods, which is forbidden by Brazilian law. This underscores the need for stricter policies and enhanced supervision to promote a healthier school environment and combat obesity.

These results also point to an environment with a higher propensity for NCDs incidence in adulthood. Because food preferences and habits are acquired during early childhood and are ratified throughout life under genetic, cultural, environmental and emotional factors, consolidating from the supply and availability of food (FISCHER, 2018, CUNHA; HECKMAN; SCHENNACH, 2010). Therefore, food safety and preventive health policies are important, as they can promote a healthy quality of life from the earliest years.

Baker *et al*. (2020) analyzed the nutritional transition and consumption of ultra-processed foods in five regions of the world. The authors identified a significant increase in the consumption of ultra-processed foods in developed and middle-income countries, especially among the poor and urban population. Notable, regulation of this transition has been scarce and, when implemented, has met with resistance from the food industry, thus hindering the effectiveness of efforts to promote a more conscious consumption pattern. Furthermore, a direct correlation was observed between the marketing of these foods and the prevalence of NDCs.

Camargos *et al*. (2019) analyzed disability-free life expectancy estimates in Brazil over two periods, utilizing data from the 1998 National Household Sample Survey (PNAD) and the 2013 PNS, employing the Sullivan method. The results revealed a significant increase in the life expectancy of the Brazilian population, especially in the South and Southeast regions, where individuals live longer and healthier than the national average. However, these advances were not as significant in the North and Center-West regions.

Assunção and França (2020) investigated the occupational factors associated on NCDs in Brazil, using data from the Global Burden of Disease (GBD) between 1990 and 2016, utilizing descriptive analyses. The results showed that in both the 15-49 age group and the 50-69 age group, hypertension, high cholesterol, hyperglycemia, and insufficient intake of fibre, fruit, and vegetables emerged as the main causes associated with disability, early retirement, and premature death in Brazil.

Finaret and Masters (2019) conducted a theoretical and empirical review of the impacts of food policies in various countries, focusing on the intersection between economics and nutrition. The conclusions emphasized the effectiveness of government programs and initiatives in promoting the health of the population. Additionally, the study highlighted that inadequate nutrition not only harms child growth but also compromises cognitive development and human capital potential. It is important to emphasize that the availability of healthy food has as important an influence as increasing income since improving food quality directly affects health conditions.

Li *et al*. (2006) investigated the risk of cardiovascular disease in relation to levels of Body Mass Index (BMI) and Waist-to-Hip Ratio (WHR) in the population aged 45 to 73 in Malmö, Sweden, using statistical methods of linear regression, logistic regression, and multivariate analysis with data from the Malmö Diet and Cancer. The results showed that high levels of BMI and WHR are significant predictors of cardiovascular disease risk, particularly in women, and are associated with a higher prevalence of hypertension and diabetes.

Silva, Souza, and Balbinotto Neto (2017) examined the relationship between obesity and labor income by gender in Brazil, using data from the 2013 PNS. Using quantile regressions and the matching method, they identified a positive and significant association between body weight and men's salaries. However, when considering the pairing of individuals with similar characteristics, except for the degree of obesity, the results showed a negative and significant impact on wages for both obese men and women. This underscores the fact that obesity not only increases the risk of NCDs but can also adversely impact labor income.

Everson *et al*. (2002) showed the relationship between socioeconomic status and its effect on depression, NCDs, and obesity in the United States of America (USA). The authors found that the impact of this relationship was more pronounced in the lower socioeconomic strata, particularly among young people, and persist throughout life. It is worth noting that this economic disadvantage is cumulative and makes individuals more susceptible to future health problems.

Rosenberger *et al*. (2005) estimated the relationship between health costs, sedentary lifestyles, and obesity in West Virginia (USA), using spatial regression with data from 55 cities. The results indicated a positive correlation between health spending and the presence of cardiac treatment centers, as well as with the population over 65. On the other hand, there was a negative correlation with proximity to other states, which may have facilitated access to the health system in neighboring regions. A sedentary lifestyle was negatively correlated with the educational level of people over 25 and with the availability of public parks. Obesity was positively associated with a sedentary lifestyle. All the models showed a positive and significant spillover effect, indicating that variations in health expenditure, physical inactivity, and obesity in one city affect these same variables in neighboring cities, as well as having a direct impact on the city itself. This phenomenon may help to explain the global obesity epidemic.

Based on this section, it is clear that inadequate diet and a sedentary lifestyle are critical factors that directly impact the likelihood of developing one or more NCDs throughout life, affecting everything from cognitive development to work income, as well as being associated with early retirement and premature death. The next section will discuss the methodology adopted and the data used in this research.

Based on this section, it is evident that an inadequate diet and a sedentary lifestyle are critical factors that directly impact the likelihood of developing one or more NCDs throughout life. These factors influence everything from cognitive development to work income, as well as being associated with early retirement and premature death. The subsequent section will discuss the methodology adopted and the data utilized in this research.

METHODOLOGY

This section presents the main methodological approaches guiding this study, including exploratory spatial data analysis, the spatial panel data method, the tests employed, and the database used.

Exploratory analysis of spatial data

Exploratory spatial data analysis (ESDA) is the methodological approach used to examine how spatial autocorrelation interacts with the database and information (ALMEIDA, 2012). In the context of this study, ESDA is employed to investigate how the incidence of deaths from NCDs affects both the region to which the municipality belongs and how it is affected by nearby cities. To do this, two fundamental concepts are required: spatial weight matrices and spatial autocorrelation verification methods, with the univariate global and local Moran index.

Spatial autocorrelation can manifest itself in various ways[1] . In this study, was used spatial matrices with weights of the type contiguities (based on proximity between units) and *k*

[1] For more information, see Almeida (2012).

neighbors (with k ranging from 1 to 24[2]). To create the maps, was used the georeferenced matrix provided by the IBGE (2023), in order to observe the interconnections between municipalities. In this context, the matrix indicates one if the municipality has any connection with another and zero otherwise (ALMEIDA, 2012; CLIFF; ORD, 1981).

The spatial weight matrices were constructed using the notions used in the game of chess, to simulate the movement of the pieces. Three contiguity matrices were used: queen, rook and k neighbors. The queen matrix considers any type of contiguity between municipalities, while the rook matrix considers only the strongest connections, and the neighbor matrix considers all connections up to 24 neighbors, including 'neighbors of neighbors' (ALMEIDA, 2012). The appropriate spatial weight matrix to be used was selected based on the univariate global Moran's index statistic (STAKHOVYCH; BIJMOLT, 2009).

The univariate global Moran's index (I) is used to assess how the rate of deaths from NCDs interacts with the environment, considering the existence of spatial dependence between municipalities. The index measures the proportion of deviations from the mean in spatial autocorrelation and varies between $-1 < I < 1$. A value close to zero indicates no spatial dependence, while a value closer to one indicates spatial autocorrelation, which can be positive or negative (ALMEIDA, 2012). The index is represented by:

$$I = \left(\frac{n}{\sum_{i=1}^{n} W_{ij}}\right)\left(\frac{(\mathrm{DCNT})' W (\mathrm{DCNT})}{(\mathrm{DCNT})'(\mathrm{DCNT})}\right) \quad (1)$$

where I is the univariate global Moran's index; n is the number of spatial units (5570 cities in this study); $\sum_{i=1}^{n} W_{ij}$ the sum of the elements of the spatial weights matrix W, where j denotes the values of neighboring cities close to i; and DCNT the vector representing the rate of deaths from NCDs per 100,000 inhabitants.

The univariate local Moran's index (I_i), also known as local indicators of spatial association (LISA), calculates the specific spatial autocorrelation for each city in relation to the others, making it possible to identify and analyze the formation of clusters and the behavior of these concentrations. O I_i classifies spatial dependence into four categories: high-high (HH), when high values are clustered together; low-low (LL), when low values are close to each other; high-low (HL), when a city with a high incidence rate of NCDs, for example, is located in a region with a predominantly low incidence; and low-high (LH), when a municipality with low prevalence is adjacent to cities with high NCDs rates.

[2] The maximum number of municipal contiguities observed in Brazil is twenty-three.

Values of I_i greater than zero indicate similarity between the units (AA, BB), less than zero disparities (AB and BA), and a value of zero indicates no clusters. The equation for this statistic is represented by:

$$I_i = (\mathrm{DCNT}_i) \sum_{j=1}^{J} W_{ij} (\mathrm{DCNT}_j) \quad (2)$$

where I_i is the univariate local Moran's index; DCNT_i is the rate of deaths from NCDs per 100,000 inhabitants in the city i; DCNT_j the value of the observation in the region close to i; and $\sum_{j=1}^{J} W_{ij} (\mathrm{DCNT}_j)$ the sum of the elements of the contiguity matrix W multiplied by the vector of observations in the region's contiguities i (ALMEIDA, 2012).

Verifying the existence of spatial behavior in the data is important because, as observed by Rosenberger *et al.* (2005), NCDs can be correlated with the environment, justifying the empirical test for Brazil. If the presence of spatial behavior in the data was not confirmed, the classic linear econometric methodology would be used.

Specification of Econometric Models

Given the existence of spatial behavior in the data, the classic method can lead to bias and inconsistency, which justifies the need for methods and models that take this particularity into account. Thus, econometric models of spatial panel data are specified, which, like the classic models, can be divided into fixed effects (FE) and random effects (AE). And the Hausman test is used to select the type of unobserved effect (FE or AE) most suitable for estimating the model (GREENE, 2012).

The first model is the classic panel data model with EF, which is specified as follows:

$$\mathrm{DCNT}_{it} = \alpha_i + \beta X'_{it} + \varepsilon_{it} \quad (3)$$

where DCNT_{it} is the vector of the dependent variable, in the municipality i in the year t where $i = 1, 2, 3, \cdots, 5570$ e $t = 2013, 2014, 2015, 2016, 2017, 2018, 2019$; α_i report the unit fixed effects i; X_{it} is the vector of independent variables; β is the transposed vector of parameters; and ε_{it} the error term of the randomly distributed model.

The classic panel data model with RE can be defined as follows:

The classic panel data model with EA can be defined as follows:

$$\mathrm{DCNT}_{it} = \alpha + \beta X'_{it} + \xi_{it} \quad (4)$$

$$\xi_{it} = \omega_i + \varepsilon_{it} \quad (5)$$

Where α is intercept of model; ξ_{it} it is the composite error term; and ω_i represents the random effects, which are constant over time.

However, the classic panel data model does not take spatial autocorrelation into account. Therefore, to overcome this limitation, some spatial panel data models are presented, namely: SLX, SAR, SEM and SAC. It should be noted that the models mentioned below are discussed in general terms and incorporate unobserved effects, i.e. both FE and AE. A Hausman test will then be carried out to determine the most appropriate approach for dealing with unobserved effects.

The Spatial Model with Lag in X (SLX) incorporates the spatial lag only in the independent variables and is specified as:

$$\text{DCNT}_{it} = \alpha_i + \beta X'_{it} + \theta W_i X_{it} + \xi_{it} \quad (6)$$

where θ is the parameter that captures the spatial dependence of the independent variables and W_i represents the spatial weighting matrix (ELHORST, 2014).

The Spatial Autoregressive Model (SAR) captures spatial dependence by lagging the dependent variable and can be described by:

$$\text{DCNT}_{it} = \alpha_i + \rho W_i \text{DCNT}_{it} + \beta X'_{it} + \xi_{it} \quad (7)$$

where ρ is the parameter that reports the effect of how much a variation in the average rate of deaths from NCDs in a city can affect neighboring municipalities (ELHORST, 2014).

The Spatial Error Model (SEM) considers the possibility of spatial interactions between unobserved variables, which are incorporated into the error term, represented by:

$$\text{DCNT}_{it} = \alpha_i + \beta X'_{it} + \xi_{it} \quad (8)$$

$$\xi_{it} = \lambda W_j \xi_{it} + \omega_i + \varepsilon_{it} \quad (9)$$

where λ reflects the spatial dependence of the error term, representing unmodeled effects or the absence of available measurable variables (ELHORST, 2014).

The Spatial Autoregressive Combined (SAC) model is an extension of SAR and SEM, i.e. it considers both the spatial lag of the dependent variable and the error term, and can be specified as follows:

$$\text{DCNT}_{it} = \alpha_i + \rho W_i \text{DCNT}_{it} + \beta X'_{it} + \xi_{it} \quad (10)$$

$$\xi_{it} = \lambda W_i \xi_{it} + \omega_i + \varepsilon_{it} \quad (11)$$

These models aim is to empirically verify evidence of correlation between deaths from NCDs and public spending on health and education, including the possibility of spatial interaction between municipalities. It should be noted that the models were estimated using the maximum likelihood method.

Source and Database

Four variables were chosen for analysis at municipal level: the dependent variable is the rate of deaths from NCDs in the 30-69 age group, per 100,000 inhabitants, provided by the Mortality Information System (SIM). The independent variables include per capita public spending on outpatient care related to NCDs, in the 30-69 age group, sourced from the Outpatient Information System (SIA), and per capita spending on hospital care related to NCDs, obtained from the Hospital Information System (SIH); and per capita spending on education from the Brazilian Public Sector Accounting and Tax Information System (SICONFI) of the National Treasury Secretariat (STN). It should be noted that all spending has been adjusted to 2019 values by the National Consumer Price Index (INPC) of the Brazilian Institute of Geography and Statistics (IBGE). The data covers the period between 2013 and 2019.

NCDs were defined and classified according to the International Classification of Diseases (ICD-10), using the criteria described in the information note on the methodological aspects of the coefficient of premature mortality due to noncommunicable diseases (BRAZIL, 2018). To calculate the NCDs death rate, deaths from preventable causes were taken into account, i.e. those caused by neoplasms (C00-C97), diabetes mellitus (E10-E14), cardiovascular diseases (I00-I99) and chronic respiratory diseases (J30-J35 and J37-J98) in the population aged between 30 and 69 (BRASIL, 2018).

It is important to note that the Napierian logarithm of expenditure was used in order to establish a measurement scale that improves interpretation, bringing the different scales closer together to facilitate understanding. Table 1 describes the variables used in the analysis.

Table 1 - Description of the variables used

Dependent variable	
NCD	Death rate from chronic non-communicable diseases
Independent variables	
ln(S.SIA)	Napierian logarithm of public spending on outpatient procedures
ln(S.SIH)	Napierian logarithm of public spending on hospital procedures
ln(S.Educ)	Napierian logarithm of public spending on education

Source: Prepared by the authors.

The choice to use spending on health and education as explanatory variables for the rate of deaths from NCDs is based on the understanding that these indicators play a fundamental role in health promotion and disease prevention. Health spending, represented by investments in outpatient and inpatient care related to NCDs, is a direct measure of the commitment of public resources to addressing and treating these conditions. In addition, education spending, when incorporated into the analysis, reflects the recognition of the influence of socioeconomic and educational factors on the health of the population. Since better educated individuals tend to be more informed about preventive health practices and adopt healthy behaviors, this can have a positive impact on the incidence of NCDs.

The period selected, from 2013 to 2019, was deliberately defined in order to ensure the consistency and objectivity of the analysis. The decision to start in 2013 is related to the moment when georeferenced public spending became available, while ending in 2019 aims to avoid potential interference from the Covid-19 Crisis, which emerged in early 2020. This choice therefore ensures that the results obtained are less subject to abrupt fluctuations linked to the pandemic emergency.

The following section presents the descriptive statistics, the results obtained and their respective discussion.

RESULTS AND DISCUSSION

Descriptive Statistics

The descriptive statistics for the variables are shown in Table 2.

Table 2 - Descriptive statistics

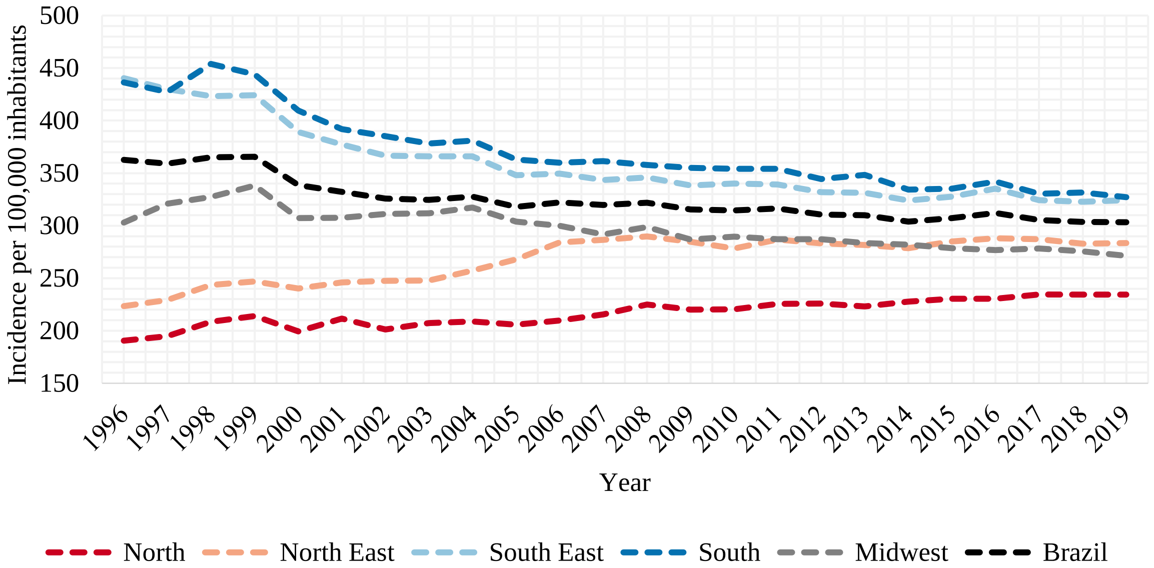
Variable	Average	Standard deviation	Minimum	Maximum
NCD	293.1708	114.7794	0	1263.1580
S.SIA	19.1770	13.8722	0	295.7750
ln(S.SIA)	2.6359	0.9737	-6.3576	5.6896
S.SIH	28.9817	19.6032	0	511.8957
ln(S.SIH)	3.1236	0.7656	-3.7221	6.2381
S.Educ	949.5614	347.8767	0.0464	6617.3760
ln(S.Educ)	6.7959	0.3535	-3.0695	8.7975

Source: Prepared and estimated by the authors using data from DATASUS and SICONFI, analyzed with Stata 15.1 software licensed under the number 401506318757.
Note: Monetary values have been adjusted to 2019 prices by the INPC.

The descriptive statistics indicate considerable variance in the data, especially in the context of public spending. This dispersion is most pronounced in spending on outpatient and hospital procedures, where certain municipalities had spending that exceeded the average by more than 15 and 17 times, respectively, for these categories. With regard to spending on education, although on a smaller scale, a similar scenario can still be observed, with some municipalities recording spending up to 7 times higher than the established average.

Figure 1 shows the average downward trend in deaths from NCDs in Brazil between 1996 and 2019. This trend provides positive evidence that access to hospital and primary health care services, combined with the global commitment represented by the Sustainable Development Goals, has played a significant role in reducing mortality rates related to NCDs. However, when analyzed at a regional level, there are pronounced disparities, especially in the North and Northeast of the country, where there is a worrying increase in the incidence of these diseases every year, while in the Midwest, South and Southeast this figure has been decreasing. Even so, the South region has a higher death rate than the North by approximately 33.5% in 2019, as shown in Figure 1.

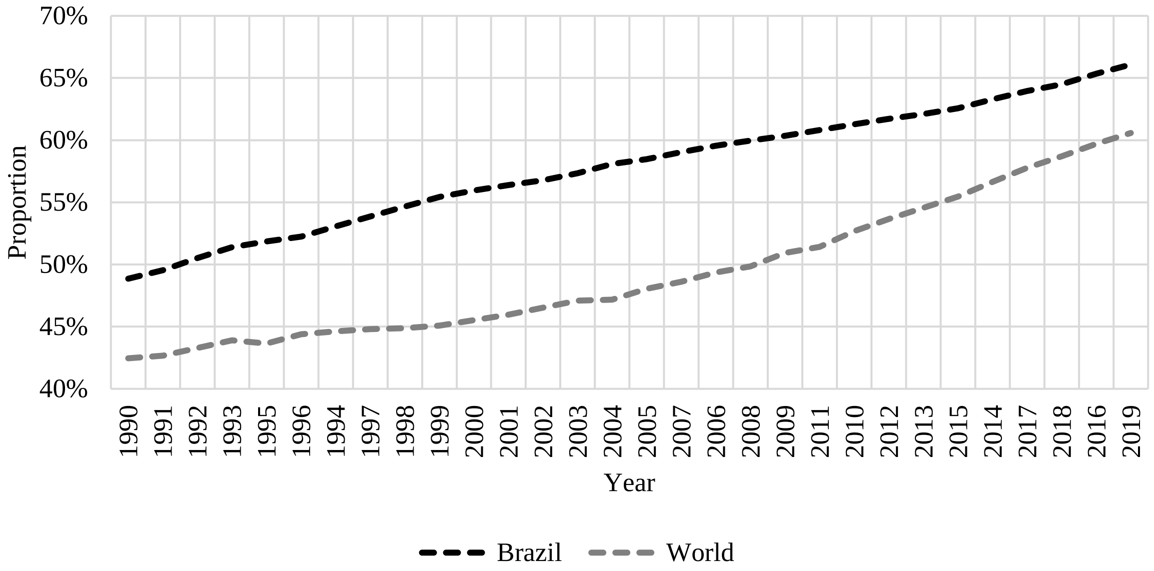
Figure 1 - Incidence of deaths from noncommunicable diseases between 1996-2019 in Brazil for the 30-69 year-old population



Source: Prepared by the authors based on DATASUS data.

When analyzing the proportion of deaths associated with NCDs relative to all other causes, including occurrences such as violence and traffic accidents, it is becoming clear that deaths from preventable causes related to NCDs have increased over the last two decades. In Brazil, these causes accounted for approximately 66% of all deaths, compared to the global average of around 61% in 2019, as depicted in Figure 2. Factors such as changes in lifestyles, an ageing population, urbanization and the nutritional transition may have contributed to this scenario. However, preventive health policies aimed at disease prevention and control are relative to addressing this challenge.

Figure 2 - Proportion of deaths from noncommunicable diseases between 1996-2019 for the population under 70 years of age in Brazil and worldwide



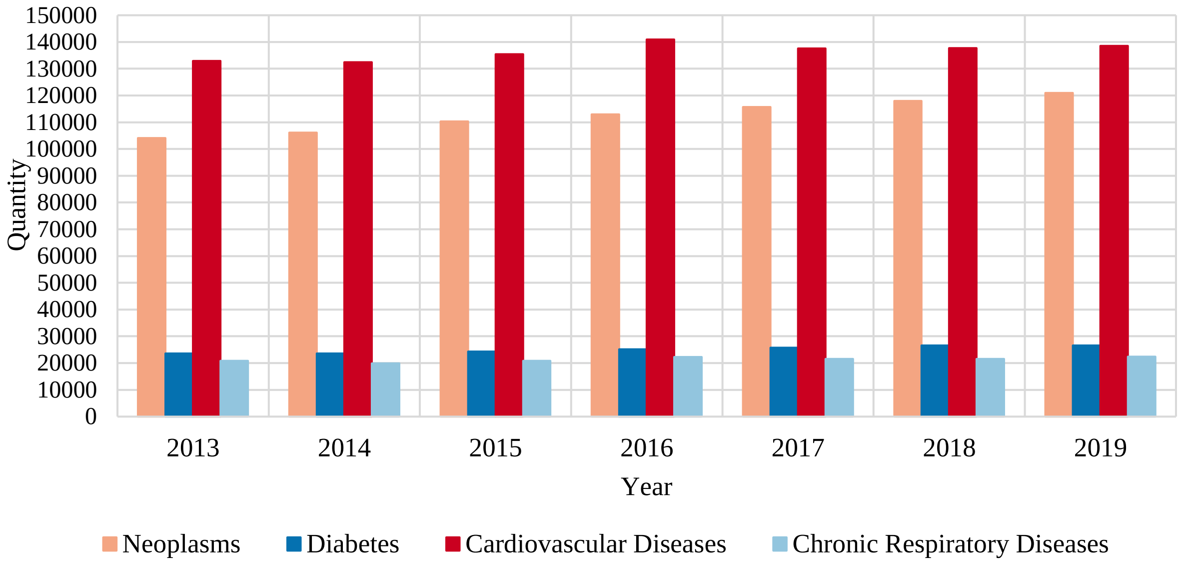
Source: Prepared by the authors based on GBD data.

Between 2013 and 2019, Brazil recorded more than 2 million deaths related to NCDs, resulting in an annual average of approximately 300,000 cases. These figures point to the magnitude of the challenge that NCDs represent for national public health. Among the main causes are cardiovascular diseases and neoplasms, which lead the statistics, followed by diabetes and chronic respiratory diseases, as illustrated in Figure 3.

When examining the categories, cardiovascular diseases are the main cause of preventable deaths, totaling more than 132,000 annual cases, reaching their peak in 2016, with 1,484 records. In second place, neoplasms emerge as responsible for causing more than 100,000 cases, reaching its peak in 2019 with 1,120,972 occurrences. Collectively, these causes account for 86% of deaths. Diabetes, for its part, contributes more than 23,000 cases, while chronic respiratory diseases account for more than 20,000 cases, corresponding to 9% and 7% of total deaths, respectively.

These data emphasize the urgency of preventive approaches and the need to formulate effective public policies to confront these risk factors. Particularly, it is essential to improve access to medical care in order to identify these conditions early. Such measures can not only mitigate this concerning trend, but also preserve lives by reducing the pressure on hospitalizations and the health system. This approach would culminate in a panorama of greater well-being for society.

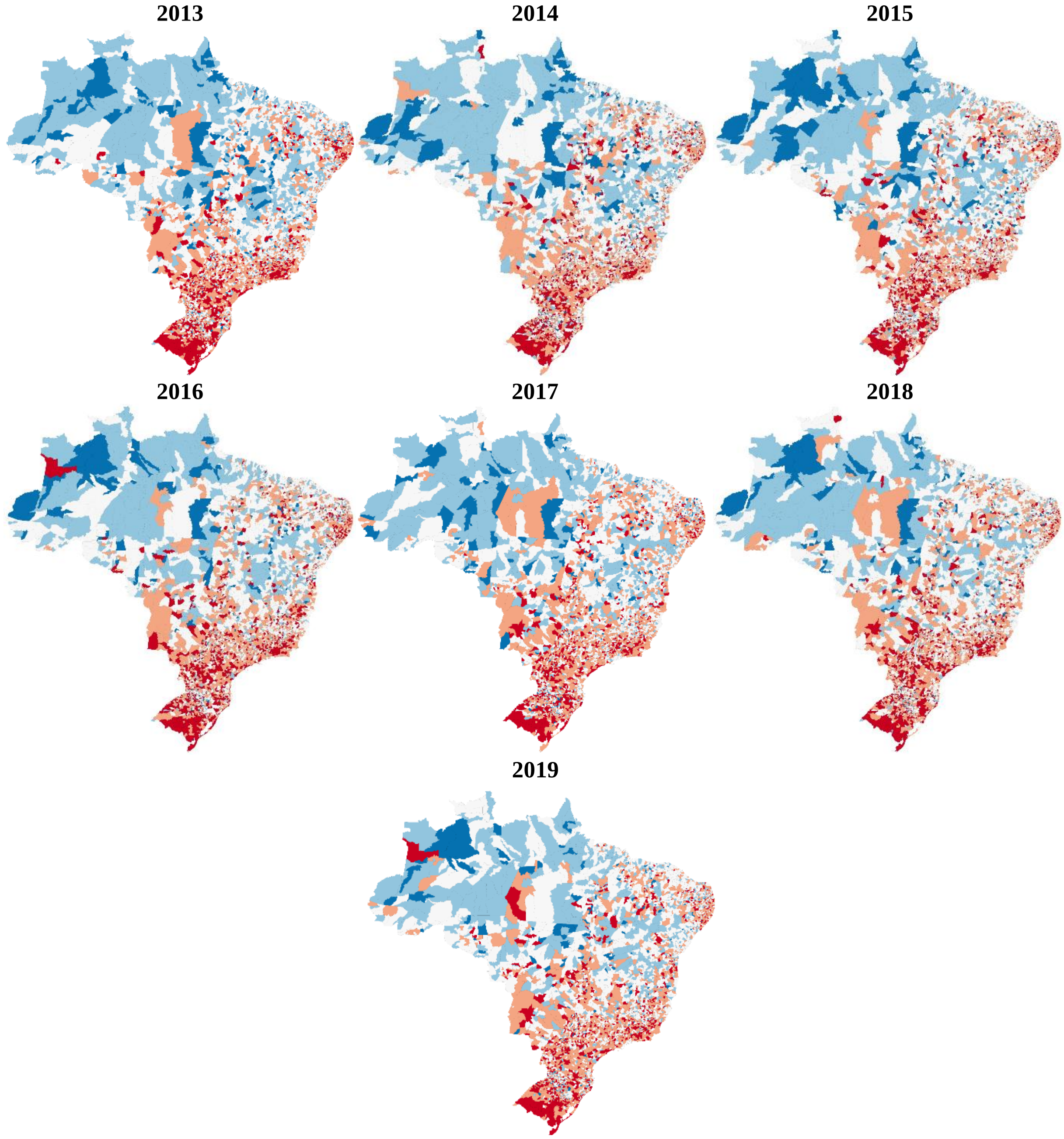
Figure 3 - Incidence of deaths by category of noncommunicable diseases between 2013-2019



Source: Prepared by the author based on DATASUS data.

Figure 4 illustrates the highest incidence in the South and Southeast regions of Brazil, as well as along the northeastern coast, especially in the States of Paraíba, Pernambuco and Alagoas. During the period between 2013 and 2019, there was a reduction in this concentration, but its relevance in these regions is still substantial. In the Central-West Region, the phenomenon is also notable on the border with Bolivia and Paraguay, as well as in the areas where the South and Southeast Regions converge. On the other hand, the North has the lowest incidence nationwide, with cases being distributed more evenly over the period under analysis.

Figure 4 - Incidence of deaths from noncommunicable diseases by municipality (2013-2019)



Caption
< 100 | [100, 200) | [200, 300] | (300, 400] | >400

Source: Prepared by the authors based on DATASUS data and analyzed GeoDa 1.18.0 software. Note: Per 100,000 inhabitants.

Details of the number of cities in each range can be found in Table 3, which shows a reduction in the number of cities with an occurrence rate of less than 100 per 100,000 inhabitants. On the other hand, the range above 300 occurrences per 100,000 inhabitants shows an increase during this period.

Moreover, Figure 4 provides initial insights that suggest the presence of spatial behavior in the data analyzed, revealing patterns of geographical distribution throughout the observed period.

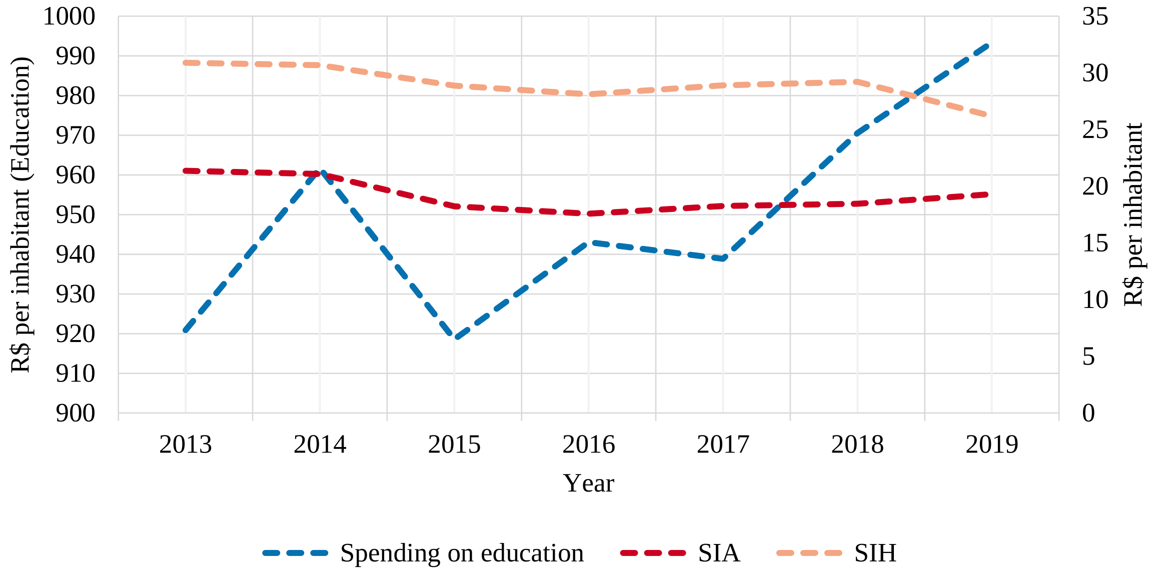
Table 3 - Number of cities by range of deaths from noncommunicable diseases between 2013-2019 per 100,000 inhabitants

Year	<100	[100, 200)	[200, 300]	(300, 400]	>400
2013	204	984	1925	1553	904
2014	229	975	1988	1600	778
2015	207	884	1981	1642	856
2016	176	854	1863	1732	945
2017	172	867	1955	1704	872
2018	167	775	2062	1694	872
2019	154	823	1977	1708	908
2020	169	809	2099	1690	803

Source: Prepared by the authors based on DATASUS data and analyzed GeoDa 1.18.0 software.

Public spending per capita on education, indicated on the left vertical axis of Figure 5, exhibited an upward trend during the period, albeit with significant variations. Conversely, spending on outpatient and inpatient procedures per inhabitant, represented on the right vertical axis, demonstrated a slight downward trend from 2013 to 2019. It is critical to note that health expenditure is associated with the volume of treatments for NCDs, given that approximately 71% of the population accesses the Unified Health System (SUS) in some capacity (BRASIL, 2021).

Figure 5 - Evolution of per capita public spending on education, outpatient and hospital production between 2013-2019



Source: Prepared by the authors using data from DATASUS and SICONFI.

Based on the analysis presented in this section, there is evidence to suggest the presence of spatial behavior in the data on deaths from NCDs each year. In view of this, specific tests will be conducted to verify the presence of spatial autocorrelation. This is done by means of ESDA, with the aim of assessing the statistical significance of this pattern and its distribution. This approach will also enable the identification of incidence clusters.

Exploratory Spatial Data Analysis of NCDs Deaths

To investigate spatial autocorrelation, all mentioned spatial weight options were explored, including the contiguities of queen, rook, and k-neighbors. The statistics of the univariate global Moran's Index were statistically significant, indicating consistent results across different weights. On this basis, queen contiguity was selected for further spatial distribution analysis, as this method encompasses all connections between territories. This decision aligns with Tobler's (1970) law of geography, which posits that everything is related to everything else, but near things are more related than distant things.

Table 4 presents the statistics of the univariate global Moran's Index for each year and type of matrix. The information contained in this table reveals substantial evidence for addressing spatial distribution when analyzing NCDs data. However, it is important to note that the univariate global Moran's Index might overlook local patterns and interactions in the distribution. To mitigate this limitation, proceeded to calculate the univariate local Moran's Index, offering a more detailed and contextualized view of spatial interactions.

Figure 6 displays the outcomes of the univariate local Moran's Index, showing the presence of significant clusters. Gray indicates no clusters; red reveals areas of high-high clustering; blue denotes areas of low-low clustering; while lilac and pink represent high-low and low-high clusters, respectively. During the analyzed period, the rate of cluster formation in Brazil fluctuated between 21% and 26%. These findings are further elaborated in Table 5, which details the number of cities within each cluster type for each year.

In the Northern Region, over the period analyzed, there was a notable concentration of the type of BB, resulting in the formation of an extensive cluster covering the entire territory. It should be noted that some cities, such as Itaituba and Altamira do Pará, had a high incidence of deaths (classified as type AB), and this situation stood out in the specific micro-regions in which these cities are located.

Table 4 - Univariate global Moran's index for the dependent variable by contiguity matrix type

Type of Contiguity	Year						
	2013	2014	2015	2016	2017	2018	2019
Queen	0.268	0.230	0.236	0.226	0.218	0.225	0.200
Rook	0.268	0.232	0.238	0.227	0.218	0.225	0.201
1 Neighbor	0.289	0.206	0.230	0.239	0.219	0.230	0.226
2 Neighbors	0.285	0.212	0.246	0.232	0.227	0.238	0.225
3 Neighbors	0.270	0.222	0.244	0.228	0.228	0.230	0.215
4 Neighbors	0.270	0.227	0.242	0.228	0.227	0.233	0.207
5 Neighbors	0.268	0.227	0.241	0.226	0.225	0.228	0.203
6 Neighbors	0.268	0.225	0.237	0.225	0.219	0.227	0.198
7 Neighbors	0.267	0.225	0.230	0.224	0.216	0.223	0.194
8 Neighbors	0.267	0.219	0.228	0.225	0.216	0.221	0.194
9 Neighbors	0.267	0.220	0.225	0.223	0.213	0.218	0.191
10 Neighbors	0.267	0.219	0.223	0.223	0.214	0.215	0.190
11 Neighbors	0.266	0.217	0.221	0.221	0.211	0.214	0.192
12 Neighbors	0.265	0.214	0.219	0.220	0.211	0.213	0.190
13 Neighbors	0.264	0.212	0.218	0.219	0.210	0.213	0.189
14 Neighbors	0.263	0.212	0.217	0.218	0.208	0.210	0.189
15 Neighbors	0.261	0.211	0.216	0.217	0.208	0.209	0.188
16 Neighbors	0.259	0.209	0.215	0.218	0.204	0.208	0.187
17 Neighbors	0.258	0.208	0.213	0.217	0.204	0.207	0.187
18 Neighbors	0.257	0.206	0.213	0.216	0.203	0.205	0.185
19 Neighbors	0.257	0.204	0.213	0.215	0.202	0.204	0.184
20 Neighbors	0.256	0.202	0.212	0.214	0.201	0.203	0.184
21 Neighbors	0.256	0.201	0.211	0.214	0.201	0.202	0.183
22 Neighbors	0.255	0.200	0.210	0.214	0.201	0.201	0.182
23 Neighbors	0.254	0.199	0.210	0.213	0.200	0.199	0.181
24 Neighbors	0.252	0.198	0.208	0.213	0.200	0.199	0.181

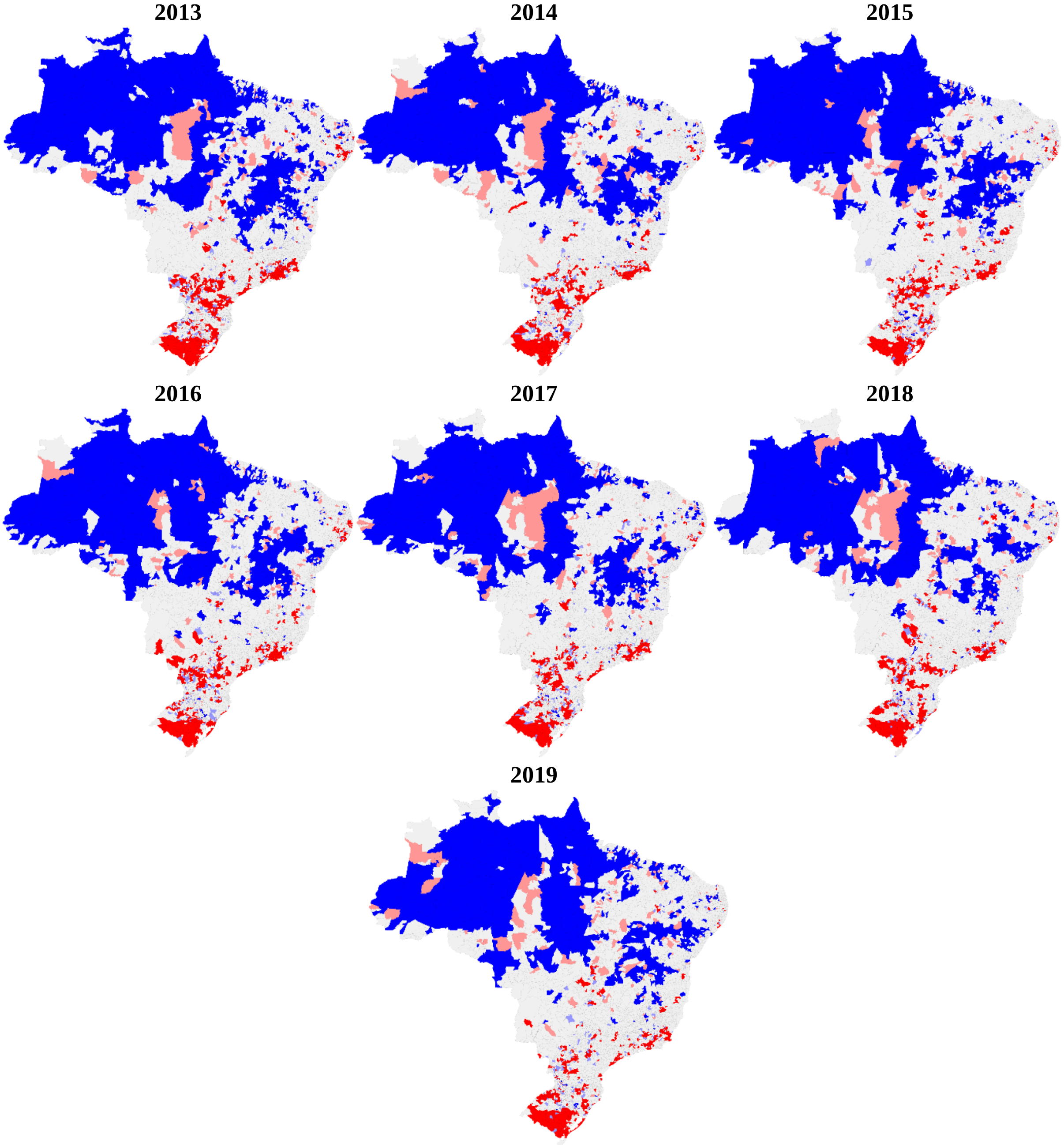
Source: Prepared by the authors based on DATASUS data and analyzed GeoDa 1.18.0 software.
Note: The significance level of the calculated statistics is given by: $-\left(\frac{1}{1-n}\right) \approx 0.0002$, where n represents the number of municipalities.

In Northeast Brazil, a BB-type conglomerate was identified between 2013 and 2019, which gradually ceased to be significant as it approached the borders with the Southeast Region. During this period, the formation and dissolution of an AA cluster was also observed between the states of Alagoas, Pernambuco and Paraíba, which emerged and disappeared in alternating years, especially in areas close to the ocean coast.

In the Center-West Region, a BB-type agglomeration occurred in the areas where the North and Northeast regions converge, covering the States of Mato Grosso and Goiás. In addition to this, another BB conglomerate formed on the border with Bolivia and persisted until the end of 2019.

In the Southeast, an AA-type cluster was identified in the States of Rio de Janeiro and São Paulo throughout the period analyzed. However, on the borders with the Northeast, a BB-type conglomerate was observed which became more intense and comprehensive over the analysis period.

Figure 6 - Univariate local Moran's index of deaths from noncommunicable diseases between 2013-2019



Caption
High-High Low-Low Low-High High-Low Not significant

Source: Prepared by the authors based on DATASUS data and analyzed GeoDa 1.18.0 software.

Note: The significance level of the calculated statistics is given by: $-\left(\frac{1}{1-n}\right) \approx 0.0002$, where n represents the number of municipalities.

In the Southern Region, AA-type clusters predominated almost exclusively throughout the period, concentrated mainly in Rio Grande do Sul, which included a significant portion of the cities and their connections with Uruguay. In addition, an AA conglomerate was identified in Paraná, especially on the borders with São Paulo and in some intersecting areas with Santa Catarina.

Table 5 - Number of cities per *cluster*

Year	AA	BB	BA	AB	No Significant
2013	566	626	163	110	4103
2014	448	567	155	107	4291
2015	464	573	136	123	4272
2016	468	547	149	123	4281
2017	424	561	169	120	4294
2018	428	567	155	128	4290
2019	363	546	145	124	4390
2020	426	504	151	127	4360

Source: Prepared by the authors based on DATASUS data and analyzed GeoDa 1.18.0 software.

The mortality rate from NCDs is concentrated in urban conglomerates in the Southeast and Northeast regions, as well as in the State of Rio Grande do Sul. This trend may be related to the socioeconomic vulnerability of the population, especially those belonging to the poorest and most urban strata (BAKER *et al.* 2020; EVERSON *et al.* 2002). Once the presence of spatial autocorrelation has been proven, proceed to the estimation of the spatial panel data models and the specification tests.

Results of the Classical and Spatial Models

The results of the classical model and the spatial FE models are presented in order to make comparisons and strengthen the robustness of the model[3]. However, based on the Akaike Information Criterion (AIC), the SEM model was selected for interpretation. The results are described in Table 8. Similarly to what Rosenberger *et al*. (2005) observed for the USA, relevant effects of the spatial distribution of the data were observed for Brazil.

[3] The following specification tests were used in the analysis: Chow test, Breusch-Pagan, Hausman, robust Hausman, White, Wooldridge and Pesaran CD (2004 and 2015), as well as the Baumont criterion. For full information, see: SIQUEIRA, Wallace Lobato. The effect of public spending on deaths from chronic non-communicable diseases. 2023. 44 p. Monograph (Specialization in Statistics and Quantitative Modelling) - Federal University of Santa Maria, Santa Maria, RS, 2023. Available at: http://repositorio.ufsm.br/handle/1/30147. Accessed on: 24 Dec. 2023.

The results show that public spending on health had a positive effect on the mortality rate from NCDs. It was observed that for each 1% relative change in resources allocated to outpatient and hospital procedures, there was an increase of 0.08 and 0.18 deaths per 100,000 inhabitants, respectively. A similar result was identified for spending on education, showing an increase of 0.07 deaths per 100,000 inhabitants.

These results, although paradoxical, can be attributed to the possible late diagnosis and treatment of these diseases. In addition, regions with a higher incidence of NCDs may allocate additional resources to the health sector as a strategy to combat these problems. In this way, it is possible that the mortality rate is influencing increased investment in health and education, thus reversing the expected causal relationship.

Table 6 - Model regression results

Variable	**EF** **p-value**	**SLX** **p-value**	**SAR** **p-value**	**SEM** **p-value**	**SAC** **p-value**
ln(S.Educ)	7.3754 * **0.0752**	-	7.3382 ** **0.0246**	7.3242 ** **0.0252**	7.3058 ** **0.0260**
ln(S.SIA)	8.3189 *** **0.0000**	-	8.3204 *** **0.2889**	8.3496 *** **0.0000**	8.3913 *** **0.0000**
ln(S.SIH)	18.7748 *** **0.0000**	-	18.8153 *** **0.0833**	18.9612 *** **0.0000**	19.1810 *** **0.0000**
Constant	162.48 *** **0.0000**	-	-	-	-
θ.ln(S.SIA)	-	8.6337 **0.2924**	-	-	-
θ.ln(S.SIH)	-	-0.3793 **0.8797**	-	-	-
θ.ln(S.Educ)	-	-10.0543 ** **0.0100**	-	-	-
ρ	-	-	0.0247 ** **0.0309**	-	-0.0530 **0.2359**
λ	-	-	-	0.0291 ** **0.0109**	0.0791 **0.0654**
R^2	0.1434	0.0371	0.1434	0.1435	0.1419
AIC	457727	397749.2	397489.4	397487.6	397488.2

Source: Prepared and estimated by the authors using data from DATASUS and SICONFI, analyzed with Stata 15.1 software licensed under the number 401506318757.
Note: Robust standard errors are presented in bold.

Another determining factor that may be influencing these results is the quality of spending. Although resources are directed towards the diagnosis and direct treatment of diseases, their allocation may not be efficient. Thus, poor management of resources or inefficiency in improving services and/or procedures can result in unfavorable consequences. This is exacerbated by the complexity and interconnectedness of the health system, where various elements, such as access to quality services, distribution of resources and public health policies, can adversely impact the relationship between spending and results.

It is important to note that investments in health and education generally generate positive long-term effects, although these results may take a while to manifest themselves. Therefore, over a short period, the increase in spending may not be immediately reflected in a reduction in the mortality rate. Becker and Siqueira (2022), when analyzing a longer period, found negative and significant evidence of the effects of health spending on deaths from NCDs in the school-age population. However, Rosenberger *et al.* (2005), like this study, also identified a positive correlation between health spending and the treatment of heart disease.

Education is also emerging as a potential tool for reducing deaths from NCDs. Malta *et al*. (2017) found that the groups most susceptible to NCDs are those with low levels of education. Everson *et al.* (2002) corroborate this point by indicating that those with lower educational levels and greater economic vulnerability are more affected by these diseases. This highlights the importance of expanding the Family Health Program with a focus on preventing and controlling these diseases.

The spatial parameters proved to be significant in both the SAR and SEM models. In the case of the SEM model, the coefficient was approximately 0.03. This indicates the existence of a positive spillover association of the effects of NCDs deaths to neighboring municipalities, using the Queen-type contiguity approach. The positive nature of this coefficient suggests that an increase in deaths in one municipality can contribute to an increase in adjacent cities. However, it is important to note that these effects are captured from the model residuals, which suggests that factors not included in the model are exerting an influence on the mortality rate.

The results indicate that public spending on health and education has an influence on deaths from NCDs, but not as expected. However, more in-depth data is needed for a more precise measurement of the coefficients, in order to more effectively capture the causal effect of spending. In addition, public policies aimed at healthier eating, encouraging physical exercise and campaigns to promote healthy habits could help mitigate this problem. This, in turn, could also reduce absenteeism and promote a more substantial accumulation of human capital.

CONCLUSION

Health plays a fundamental role in a country's economy. However, it is alarming that more than 300,000 lives are lost every year in Brazil due to preventable causes, affecting people of working age. Given this problem, this study aimed to investigate the presence of spatial autocorrelation in deaths from NCDs and to analyze the effects of public investments in health and education on the incidence of preventable deaths. For the regression, a spatial fixed effects data panel was used at the municipal level for the period between 2013 and 2019.

The results revealed the existence of a spatial spillover effect on the NCDs mortality rate. In addition, it was found that spending on outpatient procedures, hospitals, and education had a positive impact on the incidence of deaths, with coefficients of 0.08, 0.18, and 0.07, respectively, per 100,000 inhabitants. These results may indicate that regions with higher mortality rates are allocating more resources than average to health and education as a strategy to combat these problems. In this way, the mortality rate may be influencing increased investment in these areas, reversing the expected causal relationship.

The identification of the spatial spillover phenomenon highlights the importance of using this approach to formulate public policies, taking into account regional particularities and the effects that interventions can have beyond municipal borders. Although there has been a reduction in the overall mortality rate from NCDs in the country, indicating advances in public health initiatives and medical care, the analysis also highlights the persistence of regional disparities, especially in the North and Northeast regions, where deaths from NCDs have increased to the regional average. This highlights the need for specific strategies to address the challenges of these areas, ensuring more equitable access to the health system.

The unexpected positive relationship between public spending on health and education and NCD mortality rates raises questions about the allocation and use of resources. This calls for a critical analysis to understand the underlying mechanisms that drive this seemingly contradictory association. Additional research is needed to discern in detail the factors that influence this relationship, potentially providing valuable insights into accessibility to health services, early detection of diseases, and the effectiveness of health programs.

In summary, this study highlights the relevance of a spatial approach to health policy formulation. And it serves as a wake-up call for policymakers to go beyond administrative boundaries and collaborate across regions in order to develop more effective interventions, taking into account the phenomenon of spatial spillover.

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Declaration of Interest
The authors declare no conflict of interest.

Financing
Own financing.

Collaboration between authors
This article was written by W. L. S. under the guidance of Professor A. M. S. and completed in the Specialization Course in Statistics and Quantitative Modelling at the Federal University of Santa Maria. Both authors took care of the dissertation part of the article.