Explaining spatial disparity in cause-specific mortality in small areas of Brazil*

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Abstract

The exact knowledge of mortality causes distribution has remained a major guide for public health policies and planning of population health. In developing countries, however, such understanding imposes challenges as the epidemiological transition, in many cases, does not follows the traditional path from infectious diseases to man-made mortality. This study aims to examine if there are substantial spatial variations in five mortality causes, classified by the 10th ICD, among 645 municipalities in the Brazilian state of São Paulo, between 2014 and 2016. We applied Bayesian models and estimated explicative models according to a number of socioeconomic variables. Our results show that the years of schooling and sex play an important role to explain cause mortality differentials in these areas. As education increases, reduces males' chances to die from neoplasm and cardiovascular diseases. However, males with more years of schooling experience more deaths due to external causes.

Keywords: Causes of Death, Small Areas, São Paulo, Brazil

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Introduction

The knowledge of mortality distribution among group of individuals has remained a major guide for public health policies and planning of population health. Wide geographical disparity has always been a common feature of population health. In most developing countries, the lack of proper estimates at small scale aggregations have continued to hamper effective planning, implementation and evaluation of health policies at the sub-national levels. Social science theories have considered the characteristics of residential environment and socioeconomic status composition as factors influencing the well-being of individuals (Ghosn et al., 2017). These two components normally impact on stress level, physical activities, healthier diet and the general healthy lifestyle behaviour (Duncan et al., 1996; Link & Phelan, 1995).

The spatial and temporal variations in mortality have been major issues in demographic studies over the years, because they are pivotal to understanding the key determinants of mortality change (Reid & van den Boomen, 2015). Information from the analysis of cause-specific mortality is highly insightful as it embraces both disease incidence, which explains preventive measures and risky lifestyle, and chances of survival from ailment, a measure associated with a country's health care system. In Brazil, however, reliable estimates on mortality by cause of death have been restrained by lack of quality data especially at some small area levels. Though of recent, significant improvement has been made to improve the quality information on health and mortality at all levels (Junior et al., 2016; Lima & Queiroz, 2014).

Inter and intra state inequalities in mortality rates in Brazil appear to be greater than what is obtainable in the other Latin America countries (Baptista & Queiroz, 2019). For instance, studies by Baptista et al. (2018) and Baptista and Queiroz (2019) found huge inequality in mortality from cardiovascular diseases among the Federal states of Brazil. The reasons for these inequalities could hardly be deviated from the vast divergence in environmental exposure, quality of health care services and disease control among the various regions of the country (Brant et al., 2017; França et al., 2017b). Like in most developing countries, several studies have been devoted to mortality among young children in Brazil, revealing the nexus between socio and environmental conditions and mortality among this group, but that cannot be said when it comes to mortality from different causes across all ages(Almeida et al., 2014; Limaa et al., 2017; Souza et al., 2017). Additionally, expected changes in life expectancies in the near and distance future are more likely to be accounted by variations in mortality among adults and the elderly, since there are evident trend of convergence in infant and child mortality (Fadel et al., 2019; França et al., 2017a; Oliveira et al., 2016).

At the same time, the demographic and epidemiological transitions currently witnessed in Brazil characterised by decrease in mortality and fertility levels, together with an exponential rise in the number of elderly people comes with some health challenges as this group is more affected by chronic disease than any subgroup of the population. Also, there are new set of health challenges related to urbanization and industrialization such as accidental intoxication, injury, occupational and non-communicable diseases. Yet, the country is not totally free from the burden of old infectious and parasitic diseases, though mortality from these diseases are declining (Bobadilla & de A.Possas, 1993). All of that, indicates that the epidemiologic transition in Brazil has not followed the known model of the developed world (Borges, 2017; Prata, 1992). The health profile is very heterogeneous and has been referred to as epidemiological polarization (Atun et al., 2015). This pattern of epidemiological disparity complicates health transition studies and brings more challenges to demographers, epidemiologists and health experts.

Most previous studies that considered the influence of spatial covariates on adult mortality have been limited to only one or a few selected mortality causes. The spatial distributions of mortality related to neglected tropical diseases was considered by Martins-Melo et al. (2016); Queiroz et al. (2018) focuses on temporal and spatial trends in deaths due to tuberculosis, while cardiovascular diseases was considered in the work of Baptista and Queiroz (2019). In this context, the current study focuses on the analysis of spatial distributions of several causes of death, taking all within a context. We focus on the state of São Paulo and analyze cause of deaths its 645 municipalities, between the years of 2014 to 2016. This region forms an interesting case for analyses for some reason. First, São Paulo is the most populated state of the country, with 45.54 million inhabitants or 22% of total countries population (IBGE, 2014). Second, the registration of deaths count is considered moderate to good (Lima et al., 2016).

The intention of the present study is to examine if there are substantial spatial variations in mortality due to five causes, classified in the 10th international classifications of disease (ICD 10) in the state of São Paulo. This study also examines the role of socioeconomic variables including possible interactions between some of them. The impact of various intervention efforts on health care systems can be assessed if reliable mortality estimates are made available from detailed analysis of causes of mortality cutting across all ages.

1. Background of mortality profile in São Paulo

Social conditions, education and differentiated access to health services, among others, are important factors that can determine differences in mortality rates in a population (Seade, 2005). The differentiation of patterns and levels of mortality among social groups of the same society has been detected in several studies, using different analytical approaches and several social variables. In peripheral countries, most studies on health inequality have focused on child mortality and infectious disease deaths, with more recent studies addressing social inequalities targeting adult mortality (Drumond Jr & Barros, 1999).

In Brazil, São Paulo is known as one of the most successful cities in the developing world. It has the most dynamic financial market in Latin America, coupled with an efficient industrial district, and a highly sophisticated service sector. It is one of the five cities in the world where the helicopter is most used for private transportation (Akerman et al., 1994). From the beginning to the end of the twentieth century, the population of the municipality of São Paulo has increased 36 times, the number of births almost 24 and the number of deaths 13.6 times (Buchalla et al., 2003).

In the municipality of São Paulo capital, infant mortality fell progressively since the 1950s. That happened exclusively at the expense of late infant deaths. Explanations to this development are crucially attributed to reductions in infectious and parasitic diseases (Milanesi & Laurenti, 1967). In addition, socioeconomic factors are also pointed out in the literature as determinants of infant mortality reductions. Among these, the improvements in women's levels of education, the availability of piped water and sewage collection for a large part of the population, and the adoption of basic hygiene and nutrition measures or care (Murray & Chen, 1993; Powles, 1992). Not only reduction, but also the share of these diseases lost strengthen in time, as the proportion of deaths from infectious diseases declined from 45.7% of total deaths in 1901 to 9.7% in 2000 (Buchalla et al., 2003). However, other diseases and mortality causes have gained significance in present days. The changing pattern of mortality is characterized by the decline in deaths caused by infectious diseases and the increase in deaths from chronic diseases and external causes (Buchalla et al., 2003).

Among the studies, Stephens et al. (1994) discuss also differentials in intra-urban mortality rates in the city of São Paulo, showing that, at the ages of 15 to 44 years, the mortality rates from external causes of populations living in the worst socio-environmental conditions was more than double as compared with those living in more developed regions of the city. In the ages of 45 to 64 years old, the study also indicates excess deaths from cerebrovascular diseases, hypertension and traffic accidents in residents of the area with the worst socio-environmental condition. In addition, analyzing 40 years of external deaths in the municipality of São Paulo, traffic accidents were responsible for the increase of this cause of death up to 1975, while homicides became more significant during the 1980s. Thus, homicides presented a 906.8% rise in that period, especially among young people aged 10 to 24 years (Gawryszewski & Jorge, 2000).

Following this pattern of changing in profile of causes of death, we will exam in detail the evolution of death causes, but this time taking all municipalities of the State as spatial units of analyses and associating them with a number of socioeconomic characteristics.

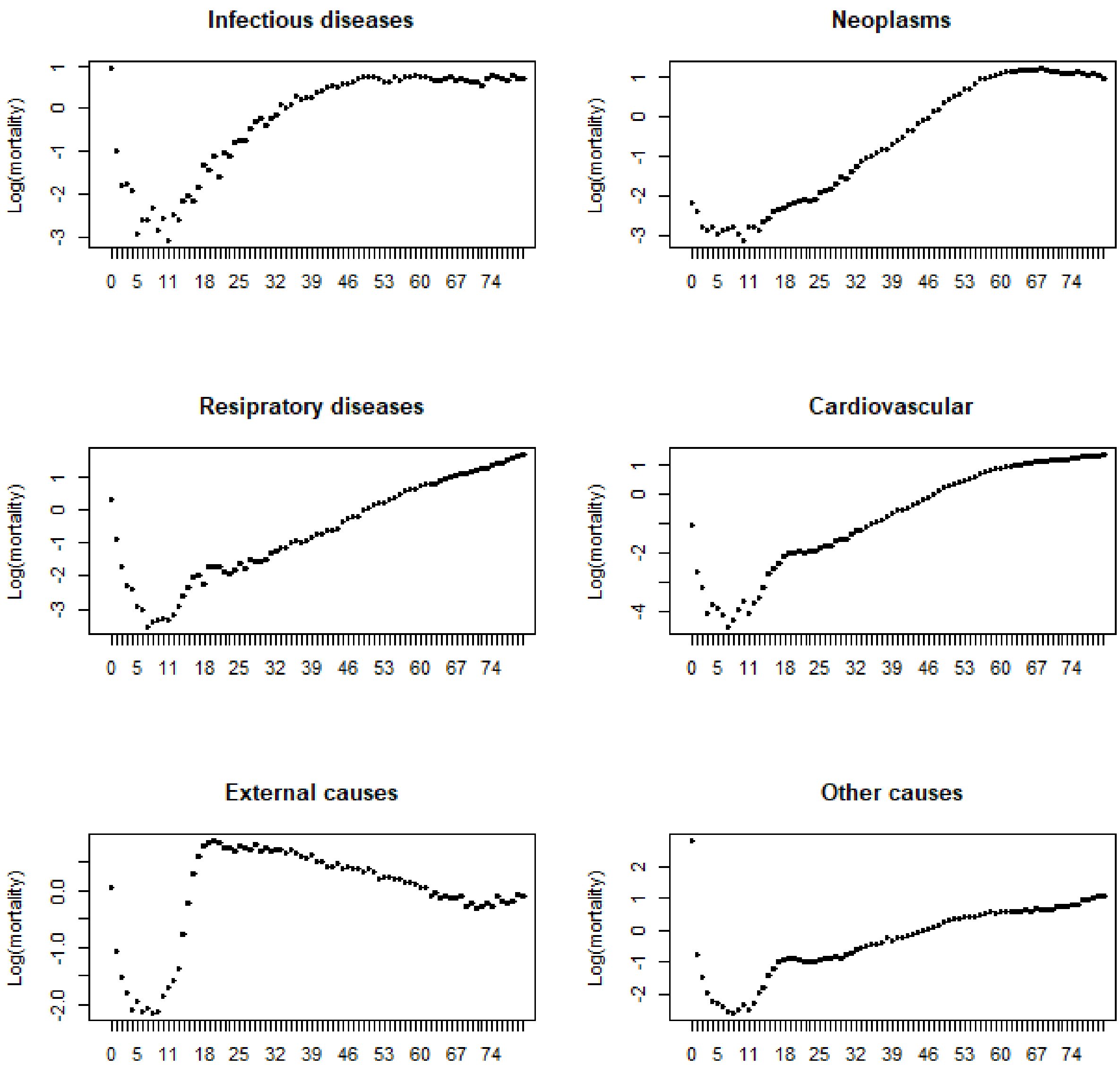
2. Data and Method

2.1. Data Sources and Level of Analysis

The study relies on publicly available mortality data from the Sistema de Informações sobre Mortalidade (SIM), DATASUS, developed by the Brazilian Ministry of Health in 1975 (www.datasus.gov.br). Information on age at death, sex, years of schooling, cause of death and the geographical location at time of death among others are included in the data source. The classification of cause-specific mortality was based on the Tenth Revision of the International Classification of Disease (ICD-10).

Figure 1 shows the plots of the average log-mortality by age for the causes of death considered, exhibiting the various familiar components of mortality curves from previous studies (Alai et al., 2014; Heligman & Pollard, 1980).

Figure 1: Observed (log) mortality by age for the different causes of death in the state of São Paulo 2014-2016.



Source: Sistema de Informações sobre Mortalidade (SIM) 2014-2016

Mortality data for the study were based on those collected in 2014 to 2016. The geographical unit used for the spatial analysis in the study was the municipalities of the state of São Paulo.

Municipalities are the smallest units for which data on mortality are registered in Brazil. Data on the population of each municipality was obtained from the 2010 population census, as documented by the Brazilian Institute for Geography and Statistics (IBGE).

3. Statistical method applied

As way to control data quality issues, the application of Bayesian modelling techniques have the ability to improve local estimates in places with limited data quality by employing mechanism that “borrow strength” from neighbouring areas sharing common boundaries (Gelfand et al., 2010). In Brazil, some attempts have been done in order to estimate mortality in small areas. For example, Gonzaga and Schmertmann (2016) proposed an adaptation of the tool for projecting age-specific rates using linear splines and applied it small areas of Brazil in 2010 to smooth mortality schedules in microregions of the country. In similar fashion, (Lima et al., 2016) proposed a hierarchical Poisson model to smooth mortality schedules in combination with formal demographic methods to assess the quality of mortality data and estimate life expectancies in municipalities from two regions of Brazil.

In our case, we are not dealing with all deaths together, but cause-specific mortality. Mortality by cause-of-death is usually a response variable with several competing outcomes. The multinomial model provides a framework for modelling a response variable with polytomous outcome and thus, the competing nature of cause-of-death has motivates researchers to find the variables that have the largest impact on cause-specific mortality. The suitability of the model is enhanced by the fact that the framework can parsimoniously quantify the impact of a confounding variable in the event that a cause is partially eliminated, if for instance, a cure is found for a specific cause (Alai et al., 2014). Thus, several applied analysis has seen the application of this approach in evaluating the impact of variables on cause-specific mortality but majorly among infant and young children.

Notable among the studies are those of Eberstein et al. (1990), Lawn et al. (2006), and Johnson et al. (2010). Studies by Park et al. (2006) and Alai et al. (2014) extend to other age range and considered the temporal effects and the possibility of forecasting future mortality. While temporal and socioeconomic characteristics are often considered, the environmental component which is vital to the well-being of individuals as earlier argued, has not been adequately evaluated.

The multinomial probabilistic model describes a polytomous response by creating a sequence of binary responses for the competing categories. Let D_{ijk} denote the random deaths from cause k by an individual I residing in municipality j, and let L_{ij} be the survivors (those whose death are not based on the specific cause) that complement the deaths. Assuming that n causes of death are considered and define Y_{ijk} as a random vector of cause-specific deaths and survivors such that:

$$Y_{ijk} = \left(D_{ij1},...D_{ijn}, L_{ij}\right) \tag{1.1}$$

If Y_{ijk} is assumed to follow a multinomial distribution, the probability mass function would be given as

$$\Pr\left(D_1 = d_1,...,D_n = d_n, L = l\right) = \frac{n¢!}{d_1!...d_n!l!} q_1^{d_1}...q_n^{d_n} p^l \tag{1.2}$$

Where $n¢$ is the total number of categories (cause-specific categories and survival), q_i is the probability of death from cause i,p is the probability of survival such that, $\sum_{i=1}^{n} q_i + p = 1$. Adopting survival as the baseline, the multinomial model can be arrived at as

$$\Pr\left(Y_{ij} = k\right) = \frac{\exp\left(h_{ij}^k\right)}{1 + \exp\left(h_{ij}^k\right)} \tag{1.3}$$

Where k = 1,...,5 the number of deaths considered and the predictor h_{ij}, omitting the superscript, can be linked to the available linear covariates and the spatial component thus

$$h_{ij} = X¢b + f(s) \tag{1.4}$$

Where, X is a column vector of all covariates, b is a vector of parameters to be estimated and $f(s)$ is a function assumed for estimating the spatial components {1,...,644} the number of municipalities in the state of Sao Paulo. We consider possible interactions among some of the categorical covariates. The multinomial model can be cast within the framework of logistic or probit model but we choose the logistic link in this study.

Parameters of the model are estimated based on fully Bayesian approach that ensures that prior distributions are assigned to the parameters of the model. The spatial component was consequently modelled through intrinsic conditional autoregressive (CAR) prior commonly used for area data and that is based on the concept of neighbourhood structures of the municipalities (Besag et al., 1991; Rue & Held, 2005). The model expresses the spatial relationship between the m municipality units and are denoted by an adjacency matrix A of dimension m' m, where the entries of A are positive if municipalities m_i and m_j share common geographical boundary and zero if they do not. This encoding of the municipalities defines a lattice structure over the m area units. The linear parameters and interactions are based on non-informative prior so that the prior has minimal impact on the posterior distribution, allowing the linear parameters to be estimated similar to the classical approach. Bayesian inference from the posterior distribution is based on Markov chain Monte Carlo (MCMC) simulation owing to the analytically intractable nature of the posterior distribution. Consequently, we ran 15,000 simulations, set the burin-in at 2,000 and sample every other 20th observation for parameter estimation. We equally performed sensitivity analysis for the hyper-parameters assigned to the CAR model which was based on inverse gamma distribution and the results turn out to be indistinguishable.

Four models of different specifications where fitted and compared. As explanatory variables, we have introduced in the models, the year of death occurrence, sex, age, years of schooling and population size (as proxy for degree of urbanization). The first model (M1) includes the spatial component and all covariates included as linear effects. The second (M2) includes an interaction term between sex and year of schooling, while the third (M3) considered interaction between sex and age. The final model (M4) includes all the linear terms and the interaction terms contained in M2 and M3. The interaction terms were added, because we believe that in terms of health studies, contextual variables are dependent of a complex interaction between individuals and the environment, and their differ according to various socio-cultural patterns (Ramos 2003; Filho et al. 2007). The model comparison was based on deviance information criterion (DIC), which is considered a Bayesian version of the Akaike information criterion (AIC). A model with minimum value of DIC among competing ones is adjudged the best.

4. Results

Table 1 presents the estimates of the model diagnostic criterion. The results show that, based on the values of the deviance, model fit improves with more interaction terms, but at slight increased complexity (values of p D). In general terms, model four (M4), comprising all the linear and interaction terms, has the best fit. Presentations of results for the linear and spatial effects will therefore be based on those of the best model.

Table 1: Coefficients of the model diagnostic criterion. São Paulo, 2014-2016.

Model	Deviance	p D	DIC
M1	1822820.07	1154.86	1825129.79
M2	1821753.20	1168.82	1824090.84
M3	1818858.72	1172.70	1821204.11
M4	1818246.77	1191.19	1820629.16

Source: Sistema de Informações sobre Mortalidade (SIM) 2014-2016.

Results for some the linear effects are presented in Table 2 while the others, years of schooling and age, and the interaction terms are plotted in order to clearly the establish differences between their sole effects and when interacted with sex, and these are presented in further Figures 2 and 3.

Table 2: Posterior estimates for some of the linear parameters. São Paulo, 2014-2016.

Parameter	Infectious diseases	Neoplasms	Respiratory	Cardiovascular	External causes
Year					
2014	0	0	0	0	0
2015	0.001 (-0.011, 0.021)	0.007 (-0.018, 0.031)	-0.005 (-0.025, 0.013)	-0.087 (-0.113, -0.061)	0.032 (0.001, 0.065)
2016	-0.016 (-0.010, 0.004)	0.067 (0.044, 0.092)	0.011 (-0.009, 0.030)	-0.166 (-0.194, -0.138)	-0.026 (-0.060, 0.008)
Sex					
Female	0	0	0	0	0
Male	0.042 (-0.034,0.113)	0.099 (0.009, 0.188)	0.120 (0.060, 0.181)	0.094 (-0.018, 0.223)	0.077 (-0.045, 0.203)
Population					
More than 500,000	0	0	0	0	0
100,001-500,000	-0.068 (-0.124, -0.008)	0.048 (-0.038, 0.139)	0.114 (0.052, 0.182)	-0.011 (-0.127, 0.277)	0.049 (-0.035, 0.145)
50,001-100,000	-0.116 (-0.180, -0.050)	0.004 (-0.085, 0.099)	0.137 (0.064, 0.223)	0.024 (-0.104, 0.145)	-0.044 (-0.247, 0.069)
20,001-50,000	-0.130 (-0.188, -0.070)	0.024 (-0.067, 0.119)	0.186 (0.119, 0.266)	0.032 (-0.094, 0.142)	-0.145 (-0.153, -0.040)
20,000 or less	-0.111 (-0.170, -0.048)	0.028 (-0.049, 0.115)	0.252 (0.183, 0.182)	0.160 (0.032, 0.278)	-0.122 (-0.035, -0.012)

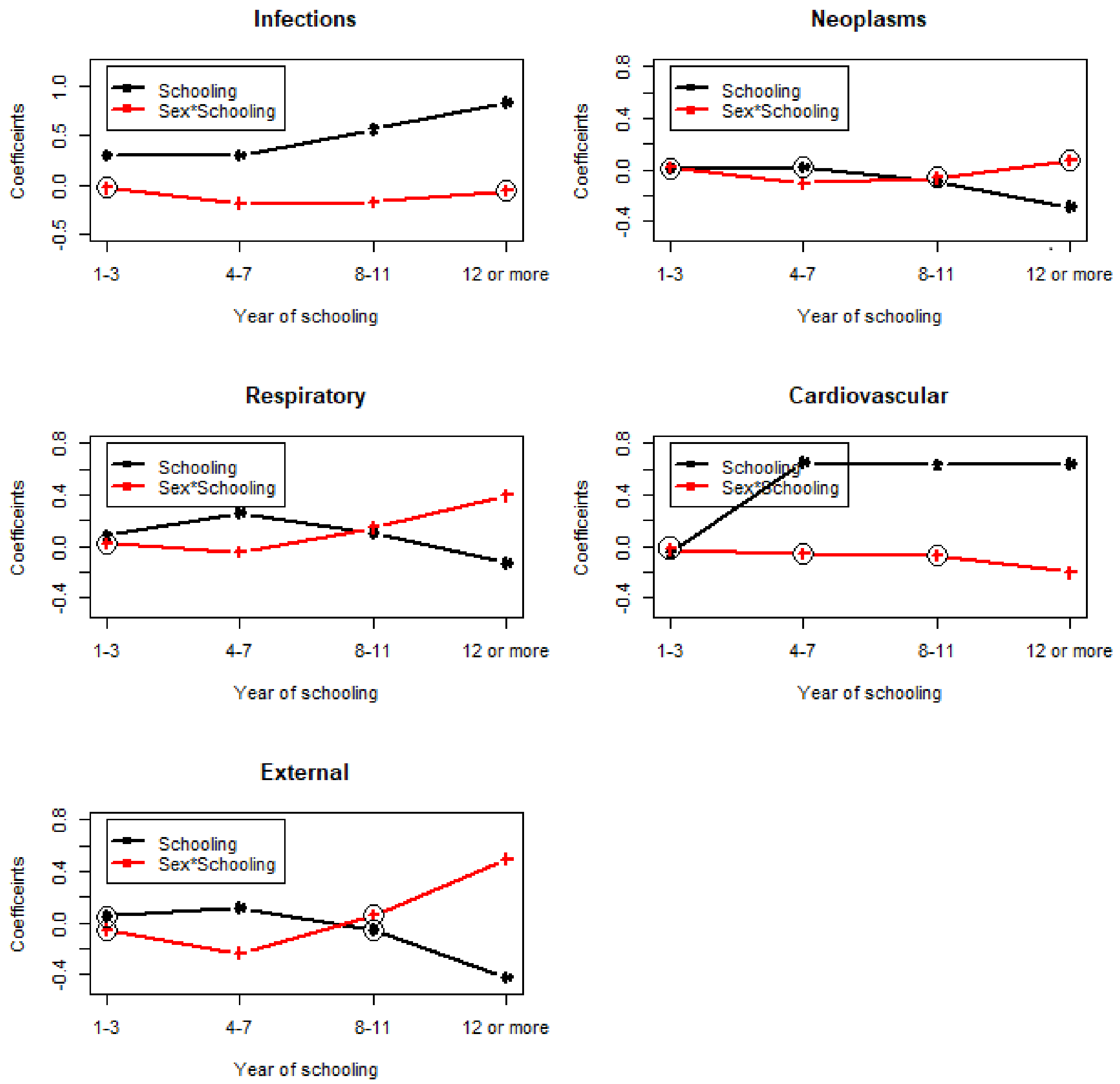
Source: Sistema de Informações sobre Mortalidade (SIM) 2014-2016.

For each of the cause of death, Table 2 presents the posterior mean estimates and 95% credible intervals. Compared with 2014 as the baseline year, the results show significant increase in mortality from neoplasm in 2016. At the same time, steady decrease in cardiovascular related mortality in 2015 and 2016. In the case of deaths from external causes, there was a significant rise in 2015. But the estimates for 2016, like those for infectious and respiratory diseases, are not significant.

The results also show that mortality from neoplasm and respiratory infections are significantly higher among male than among female, but estimates for infectious diseases, cardiovascular and external causes are not significant. As for the distribution of the population where the individuals died, findings show that, when compared with the most populated municipalities having 500,000 or more inhabitants, mortality resulting from infectious diseases was significantly lower among all the other municipalities whose population were less than 500,000 inhabitants. The exact opposite was the case for respiratory related deaths where the estimates are significantly higher. Mortality from cardiovascular causes were significantly higher among individuals who lived in less populated municipalities with 20,000 or less inhabitants, while it was lower for those with 50,000 or less in the case of deaths from external causes. This means that urban live is linked with reduction in deaths related to infectious diseases, but at the same time increases chances to other kind of mortality, as related to respiratory and cardiovascular diseases.

Figures 2 and 3 present the effects of year of schooling and age respectively including their individual interactions with sex.

Figure 2: Estimated coefficients of year of schooling and interaction between sex and year of schooling. São Paulo, 2014-2016.

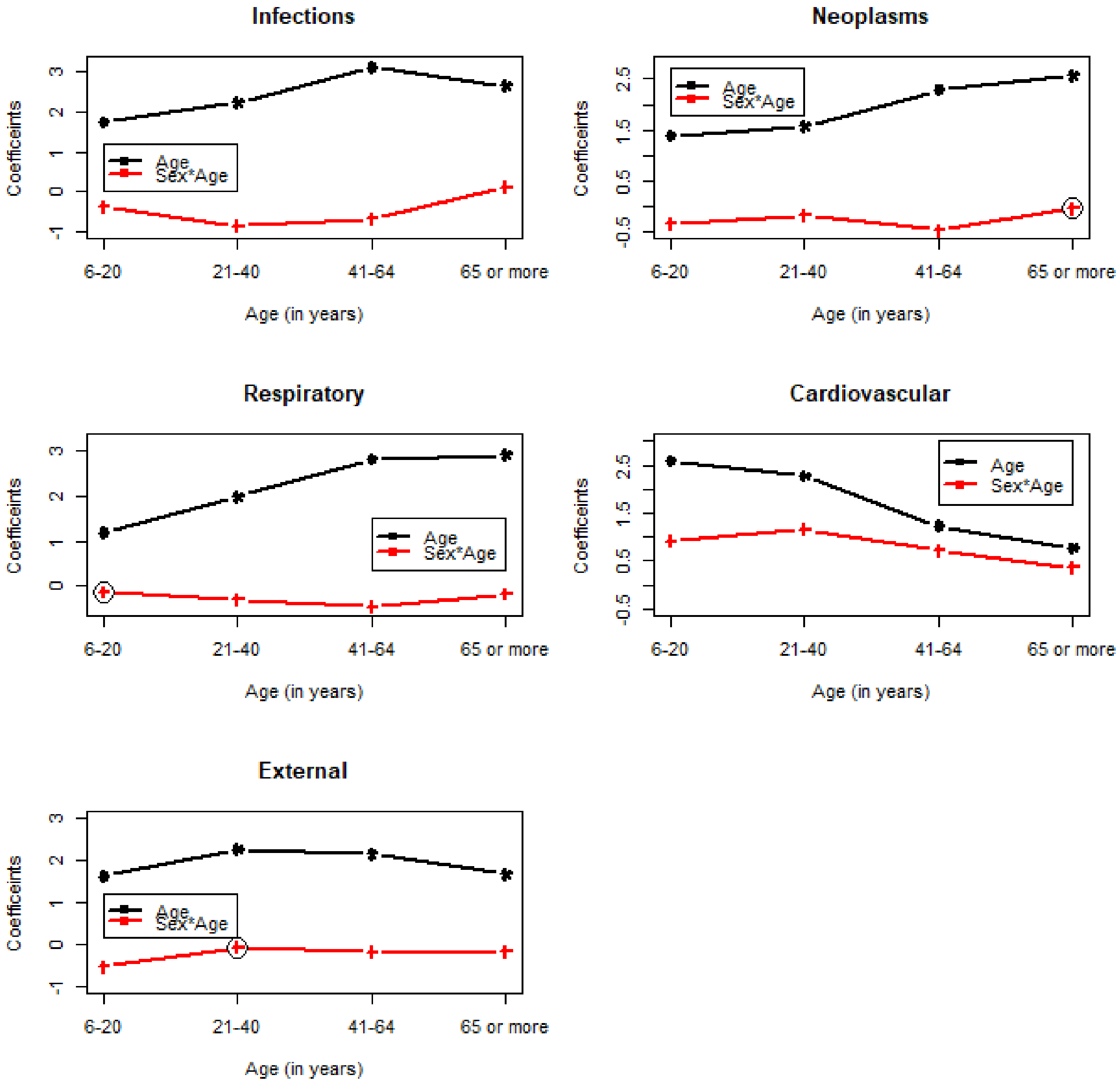


Source: Sistema de Informações sobre Mortalidade (SIM) 2014-2016.
Note: Circles indicate non-significant effect.

Non-significant estimates are indicated with a circle. Our findings show that individuals who spend at least a year in school are more likely to have died from infectious diseases and the estimates are all significant. The interaction shows that consistently, death from infectious diseases were lower for male who spent at least a year in school, though the estimates are not significant for male with one to three years of schooling and those who spent 12 or more years in school.

In addition, individuals who spent twelve or more years were less likely to have died from neoplasm related causes, while the interaction shows men who spent between four and seven years in school were less likely to have dies from neoplasm, but the likelihood of dying from this cause rises thereafter though with non-significant effect.

Figure 3: Estimated effects of age (in years) and interaction between age and sex. São Paulo, 2014-2016.



Source: Sistema de Informações sobre Mortalidade (SIM) 2014-2016.
Note: Circles indicate non-significant effect.

Mortality from respiratory causes was high among individuals who had between one and eleven years of schooling, but significantly lower for those with twelve or more years of schooling. But the reverse was the case for the interaction term which shows lower levels for those males with between four and seven years of schooling, and a significant rise in mortality thereafter. Due to job opportunities, more educated males tend to live in urban places and many respiratory diseases are linked to pollution.

Cardiovascular related deaths were peak among individuals who spent four or higher number of years in school, but the interaction shows significantly lower mortality for men with twelve or more years of schooling. That may indicate the years of schooling grant males access to healthier life styles (physical exercises, better food and diet), that in turn reduces the chances of cardiovascular deaths.

For deaths from external causes, mortality was higher among those with four to seven years of schooling, but it reduced drastically thereafter to non-significant lower levels among those who spent eight or more years in school. To the contrary, the interaction term shows that mortality was lower among men with four to seven years of schooling, but then with a rise afterwards. This probably indicates deaths related to risk live styles, as more educated males have access to the financial means, so being more exposed to common external death causes, as traffic accidents, smoke and drinks.

Results based on age reveal that mortality was significantly higher among individuals aged six years or older, rising with age, compared with those less than six years, for all the five causes considered. Interacting age and sex, however, shows that being male results in lower mortality across all ages and for all causes of death.

The estimates for the spatial effects are presented in Figures 1-5, in appendix, for each causes of death. The left panel of the figures show the posterior means for each mortality cause. The left panel presents the maps for the posterior probabilities that are used to decide the significance of the posterior means. Municipalities shaded in green colour have significantly lower mortality, but significantly higher means as compared to those with pink colour.

The estimates for municipalities shaded in grey colour are not significant. Findings show that there are significant residual spatial effects among the municipalities for all the mortality causes. The number of municipalities with significantly higher residual spatial effect for respiratory infections is more than for the other diseases, concentrating more in municipalities located in the Southern part of the state, while for the same disease, those with low estimates are more concentrated around the Northern municipalities. In the case of neoplasm, more municipalities record significantly higher estimates than those with lower estimates.

Discussion

The study on the distribution of mortality by causes is vital as it provides more insight into the burden of diseases and chances of survival of a group of people. This study simultaneously evaluates the residual spatial distributions of five major causes of death in the state of São Paulo, while controlling for important socioeconomic and demographic factors.

Although some studies have attempted to examine the spatial patterns of mortality in Brazil, they have been mostly restricted to one or few causes of death. Our approach provides insight into the relative distributions of the observed events across space at smaller area levels. We found a strong association between the various causes of mortality and the socioeconomic variables including their interactions, and the existence of residual spatial clustering across the municipalities. The spatial inequality might be related to variations in access to clean water, sanitation, and interventions in healthcare services across the municipalities (Martins-Melo et al., 2016; Martins-Melo et al., 2012).

Over the periods considered, there was a significant decline in mortality due to cardiovascular diseases. This could have resulted from the remarkable decline in mortality from cardiovascular diseases all over the world, which would have also happened in Brazil (Borges, 2017; Levi et al., 2002). Marked decline in smoking and improved access to healthcare has bred reduction in cases of cardiovascular and other non-communicable diseases in Brazil, particularly in socioeconomic more advantaged areas like state of São Paulo. Deaths from neoplasms and respiratory infections are higher among men than among women. Generally, literature has affirmed that, more men than women die from leading causes of death (Moura et al., 2016). Social differences, and search and use of health services by men have been attributed to the rising inequality in morbidity and mortality among gender in Brazil (Moura et al., 2016).

The glaring differences in neoplasms related mortality are attributed to the rising rate of mortality from prostate and colorectal cancer affecting men, while there are evidence of downward trend in breast and cervical cancer in Brazil (Conceição et al., 2014; Guerra et al., 2017). Late diagnosis due to men's restraint from prompt access to health facilities often aggravate the diseases before appropriate interventions are sought, which in turn enhances the risk of mortality. A recent study has also observed a rise in oral and pharyngeal cancer in some regions of Brazil which were attributed to changes in lifestyle that enhances the risks of exposure (Perea et al., 2018).

The drastic and significant reduction in mortality from infectious and parasitic diseases with lower population support the notion that urbanization enhances global health issues and the epidemiology of infectious diseases, because more populated areas are often incubators for several new and emerging epidemics and the zoonotic diseases can spread more rapidly (Neiderud, 2015). Mega cities in most developing countries are often heterogeneous in settings leading to improperly set out urban areas, which results in proliferation of insect and rodent vector diseases and this are sometimes compounded by inadequate sanitation, waste management and water supply. Exposure of uninfected individuals to the infected bodily fluids, feces or touch in the case of shin flora that can lead to serious infections are more common in more populated areas (Reyes et al., 2013). Aside the infants and young children who are more susceptible to infectious and respiratory diseases, aging is associated with immune dysfunction and thus, older persons have greater susceptibility to infections than the young adults.

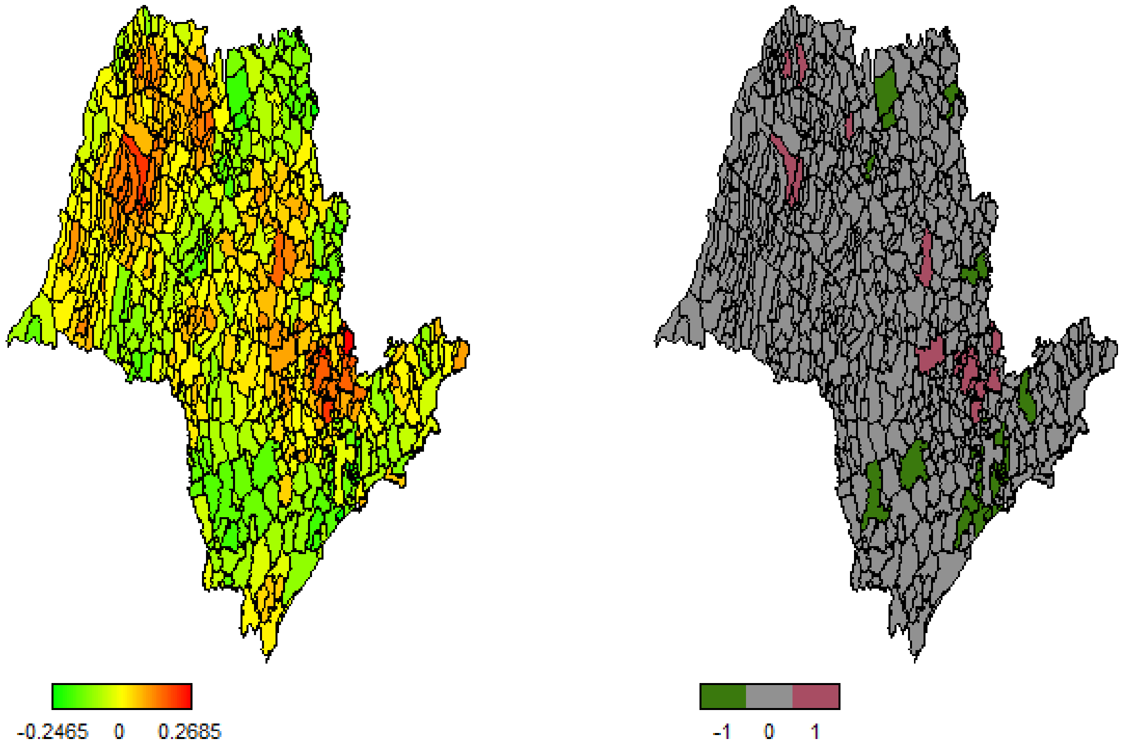
Violent crimes, drug abuse, industrial and motor vehicle accidents are also more frequent in more populated areas and enhancing deaths from external causes, especially among males, as evident from our findings. Higher chances of exposure to violence among active young individuals are often the case where there are large concentration of young people and a consequence of inadequate protective factors. Young people are often more active in drug trafficking, gangsterism and juvenile criminality and these are mediated by frequent family breakdown and the inability of public social works and police apparatus (Costa et al., 2014; Gawryszewski & Jorge, 2000).

The significant residual spatial variations for all the causes of death point to the importance of geographical space in analysing issues regarding the wellbeing of individuals. The clustering are consequences of specific geographical distribution of prevalence of the causes of death, environmental condition, migration, and differences in healthcare service provision (Martins-Melo et al., 2016).

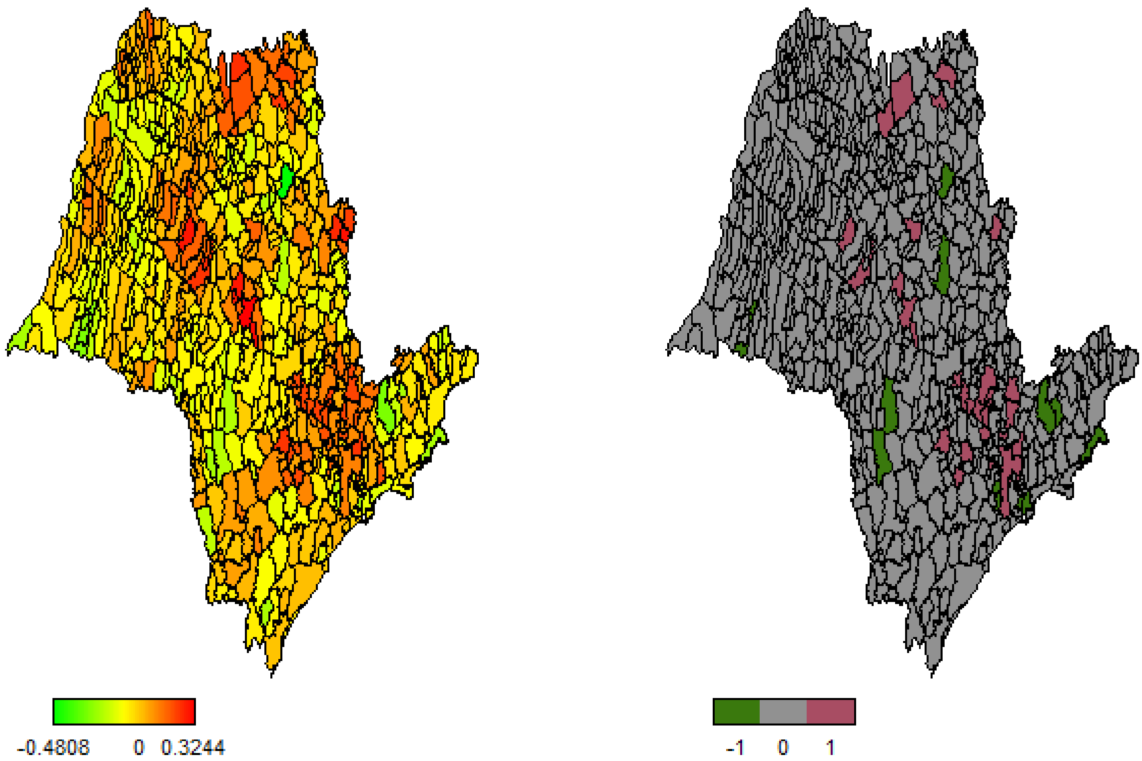
The results show less high-high clustering of mortality from infectious diseases and external causes. Obviously, government actions leading to improvement in education and generalization of healthcare services has lessen the burden of infectious diseases throughout the state, reducing inequality, but some efforts are still required so that the benefits of the actions can reach every segment of the state and Brazil at large (Borges, 2017). In the case of external causes, the fact that only a few of the municipalities are densely populated could explain why there are less clustering and previous studies have observed that the kind of violence crimes realized in major cities in the state had spread to the interiors, though there have been significant reduction in mortality from external causes in the states of São Paulo and Rio de Janeiro due to a decline in homicide rates resulting from the impact of disarmament strategies and policies to curb violence (Borges, 2017; Gawryszewski & Jorge, 2000; Waiselfisz, 2013).

Inequality from cardiovascular related deaths in Brazil are often noted in previous studies (Baptista & Queiroz, 2019). The present study shows high clustering among municipalities in the Northern part of the state could be attributed to differences in lifestyle behaviour such as smoking, hypertension and physical activities. In conclusion, mortality information by cause of death is vital for assessing the epidemiological and socio profile of a country and for simplifying the handling of socio and healthcare issues according to population needs.

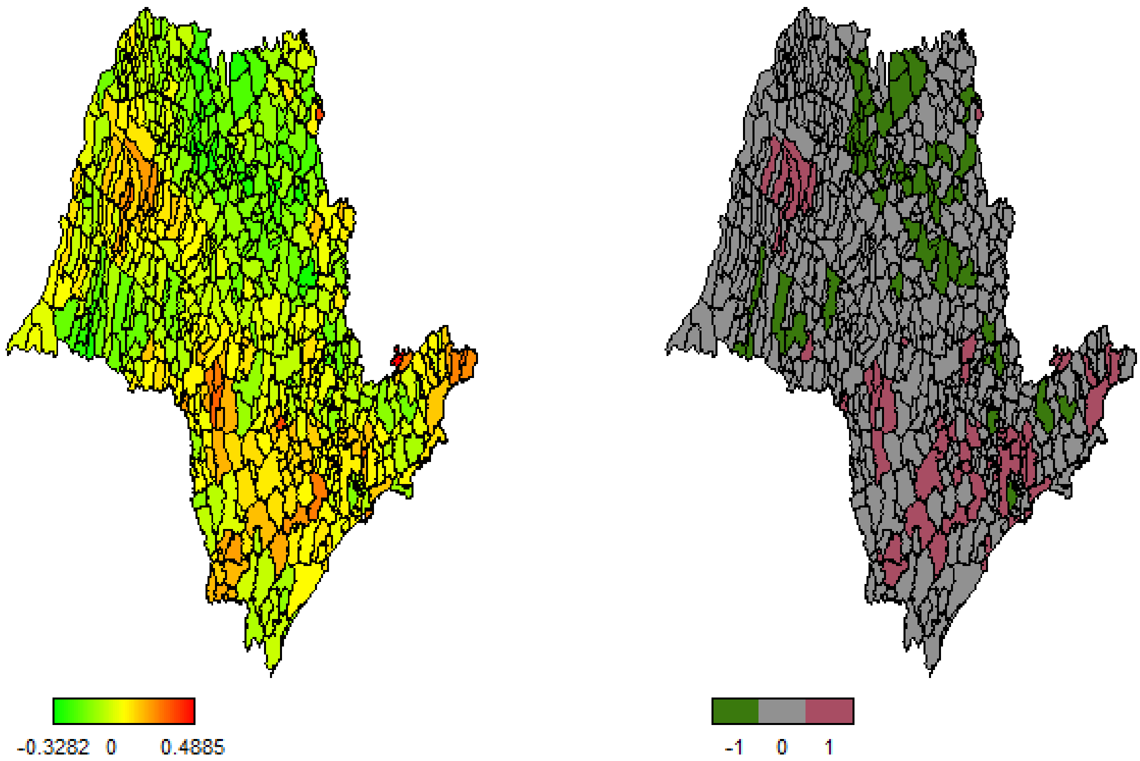
Appendix



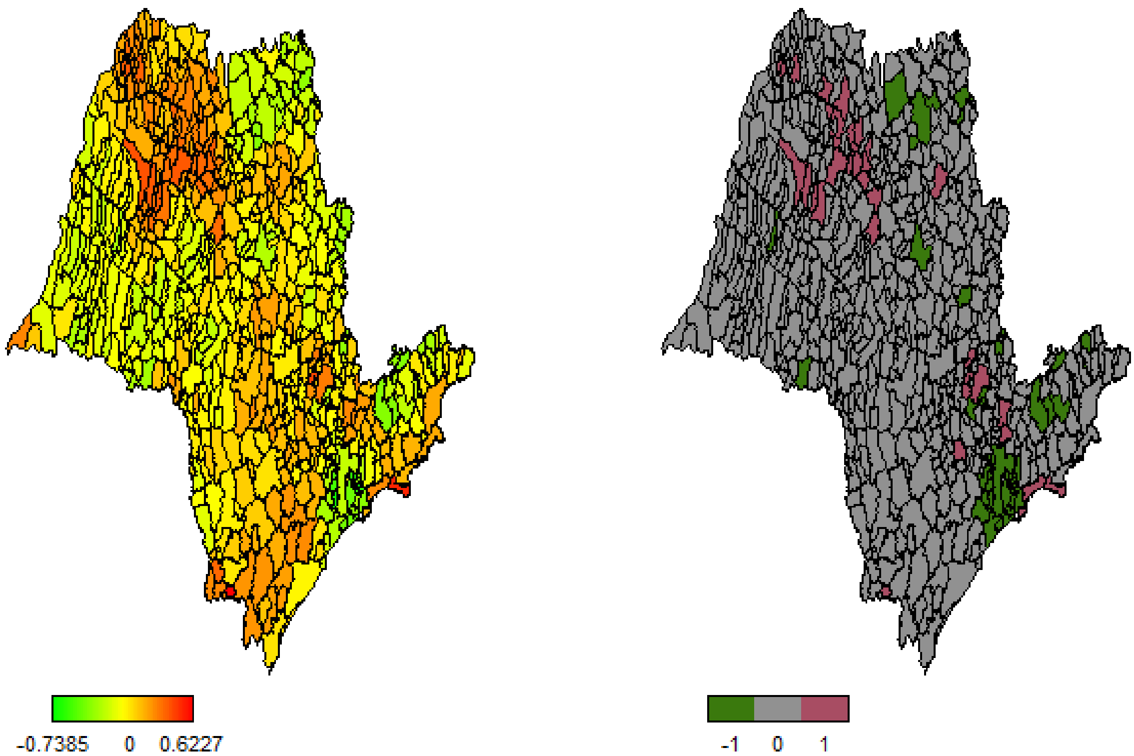
Infectious diseases



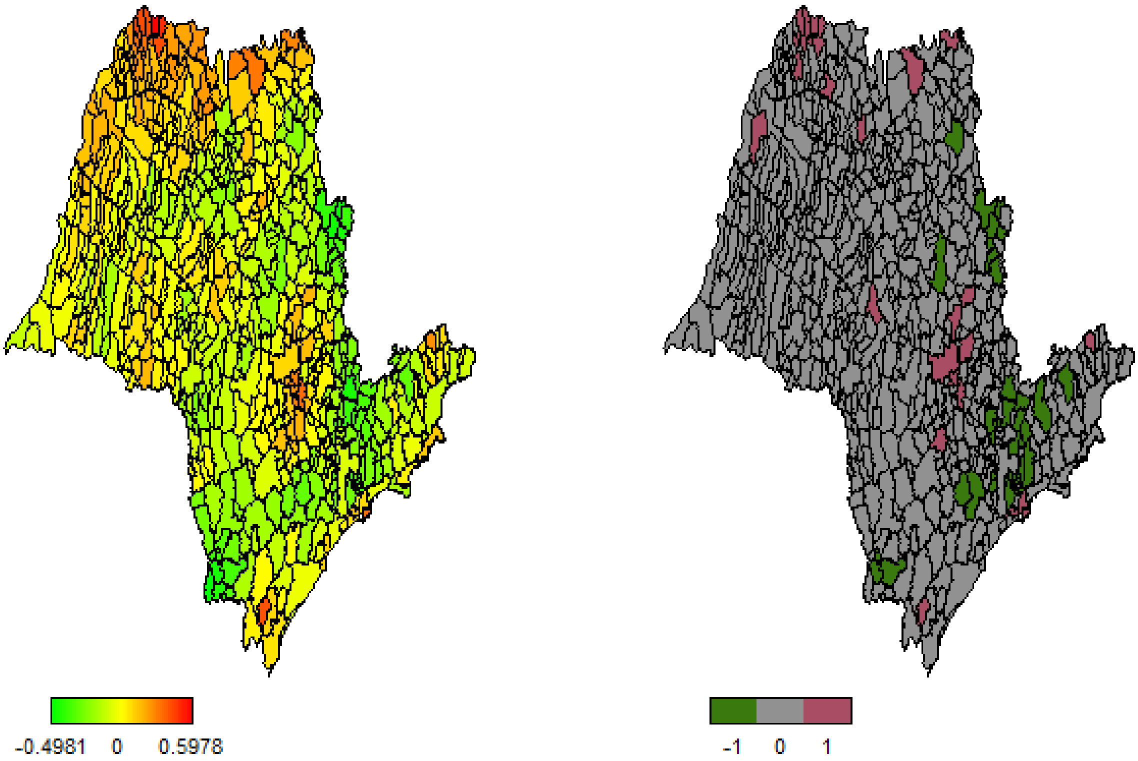
Neoplasms



Respiratory



Cardiovascular



External

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