**Supplementary material for the paper “The uneven state-distribution of homicides in Brazil and their effect on life expectancy, 2000-15”**

**Authors:** José Manuel Aburto (0000-0002-2926-6879), Júlia Calazans, Bernardo L. Queiroz, Shammi Luhar, Vladimir Canudas-Romo

**Names and Positions, Address for each author:**

Leverhulme Centre for Demographic Science and Department of Sociology, University of Oxford, 42-43 Park End Street, OX1 1JD Oxford, UK.

José Manuel Aburto, Newton Fellow

CEDEPLAR, Universidade Federal de Minas Gerais, Av. Pres. Antônio Carlos, 6627 - Pampulha, Belo Horizonte - MG, 31270-901, Brazil.

Júlia Calazans, postdoctoral associate

CEDEPLAR, Universidade Federal de Minas Gerais, Av. Pres. Antônio Carlos, 6627 - Pampulha, Belo Horizonte - MG, 31270-901, Brazil.

Bernardo L. Queiroz, professor

Department of Public Health and Primary Care, University of Cambridge, Worts Causeway CB1 8RN Cambridge, UK

Shammi Luhar, postdoctoral associate

School of Demography, Australian National University, Canberra ACT 0200, Australia

Vladimir Canudas-Romo, associate professor

**Correspondence to:**

José Manuel Aburto

42-43 Park End Street, OX1 1JD Oxford, UK.

Email: jose-manuel.aburto@sociology.ox.ac.uk

Tel: +45 31712122

ORCID: 0000-0002-2926-6879

**Section 1. Death Distribution Methods summary**

The first step of the study is to assess the quality and adjust the mortality data from states in Brazil. This analysis is done using a series of traditional demographic methods, better known as Death Distribution Methods (Hill, You and Choi, 2009). These methods were developed, based on population dynamics equations, to assess the coverage of deaths in relation to the population and the quality of the declaration of information on deaths and population. The methods compare the distribution of deaths by age with the age distribution of the population and provide the age pattern of mortality for a defined period (Murray, et.al, 2010; Hill, You and Choi, 2009). There are three main methods of evaluating the quality of mortality data: general growth balance (GGB), synthetic extinct generation (SEG) and the adjusted synthetic extinct generations (SEG-adj ). The methods have very strong assumptions: population is closed to migration or subject to very small migration flows, the degree of coverage of deaths is constant by age, the degree of coverage of the population counts is constant by age, and the ages of the living and of deaths are declared without errors.

GGB is derived from the basic demographic equilibrium equation, which defines the rate of population growth as the difference between the rate of entry and the rate of exit of the population. This relationship, according to Hill (1987), also occurs for any age segment with open interval x +, and the entries occur as birthdays at ages x. Thus, the difference between the entry rate x + and the population growth rate x + produces a residual estimate of the mortality rate x + (Hill, 1987; Hill, You and Choi, 2009). If the residual mortality estimate can be estimated from two population censuses, and compared with a direct mortality estimate using the death registry, the degree of coverage of the death registry can be estimated and mortality data adjusted (Hill, 1987; Hill, You and Choi, 2009; Murray, et.al, 2010).

SEG uses age-specific growth rates to convert an age distribution of deaths into an age distribution of a population. In a stationary population the deaths observed after a certain age x are equal to the population over the same age x, we have that the deaths of a population over age x provide an estimate of the population over the same age. Age-specific population growth rates are used to adjust the number of deaths in the stationary population for an unstable population. The sum of the number of deaths over age x gives an estimate of the population over age x. The degree of coverage of the death record will be given by the ratio between the deaths estimated by the population above age x and the population observed above age x.

Hill, You and Choi (2009) suggest a combination of the methods of GGB and SEG that can be more robust than the application of the two methods separately. The adjusted method consists of applying the GGB to obtain estimates of the change in census coverage , and using that estimate to adjust one of the demographic censuses (population enumeration) and then apply SEG method with the adjusted population to obtain the degree of coverage of the mortality data.

Although they have some limitations, DDMs provide very robust and consistent results for a series of applications across the globe. For instance, [Peralta et al., 2019](http://www.scielo.br/scielo.php?pid=S0102-30982019000100168&script=sci_arttext&tlng=pt#B21) applied the methods to evaluate data quality at the sub-national level in Ecuador. Glei, Barbieri and Santamaria-Ulloa (2019) studied the quality of mortality estimates in Costa Rica and compared to other estimates. [Wang](http://www.scielo.br/scielo.php?pid=S0102-30982019000100168&script=sci_arttext&tlng=pt#B32) et al. (2016) shows the application of DDM as part of the procedures of the Global Burden of Diseases and  [Lima and Queiroz (2014](http://www.scielo.br/scielo.php?pid=S0102-30982019000100168&script=sci_arttext&tlng=pt#B18)) evaluate quality of mortality information for small-areas in Brazil overtime.

**References**

Bennett, N. G., & Horiuchi, S. (1981). Estimating the completeness of death registration in a closed population. *Population index*, 207-221.

Bennett, N. G., & Horiuchi, S. (1984). Mortality estimation from registered deaths in less developed countries. *Demography*, *21*(2), 217-233.

Glei, D. A., Barbieri, M., & Santamaría-Ulloa, C. (2019). Costa Rican mortality 1950-2013: An evaluation of data quality and trends compared with other countries. *Demographic research*, *40*, 835.

Hill, K. (1987, May). Estimating census and death registration completeness. In *Asian and Pacific population forum/East-West Population Institute, East-West Center* (Vol. 1, No. 3, pp. 8-13). The Asian & Pacific Population Forum.

Hill, K., You, D., & Choi, Y. (2009). Death distribution methods for estimating adult mortality: sensitivity analysis with simulated data errors. *Demographic Research*, *21*, 235-254.

Lima, E. E. C. D.; Queiroz, B. L. Evolution of the deaths registry system in Brazil: associations with changes in the mortality profile, under-registration of death counts, and ill-defined causes of death. Cadernos de Saúde Pública, v. 30, n. 8, p. 1721-1730, 2014.

Murray, C. J., Rajaratnam, J. K., Marcus, J., Laakso, T., & Lopez, A. D. (2010). What can we conclude from death registration? Improved methods for evaluating completeness. *PLoS medicine*, *7*(4).

Peralta, A., Benach, J., Borrell, C., Espinel-Flores, V., Cash-Gibson, L., Queiroz, B. L., & Marí-Dell’Olmo, M. (2019). Evaluation of the mortality registry in Ecuador (2001–2013)–social and geographical inequalities in completeness and quality. *Population health metrics*, *17*(1), 3.

WANG, H. et al. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980-2015: a systematic analysis for the global burden of disease study 2015. Lancet. n. 388, p. 1459-544, 2016.

**Section 2. Decomposition method summary**

The decomposition method used in this paper is based on the line integral model (Horiuchi et al 2008). Suppose (e.g. or life expectancy) is a differentiable function of covariates (e.g. each age-cause specific mortality rate) denoted by the vector . Assume that and depend on the underlying dimension , which is time in this case, and that we have observations available in two time points and . Assuming that is a differentiable function of between and , the difference in between and can be expressed as follows:

where is the total change in (e.g. or life expectancy) produced by changes in the -th covariate, . The 's in equation (2) were computed with numerical integration following the algorithm suggested by Horiuchi et al (2008). This method has the advantage of assuming that covariates change gradually along the time dimension.

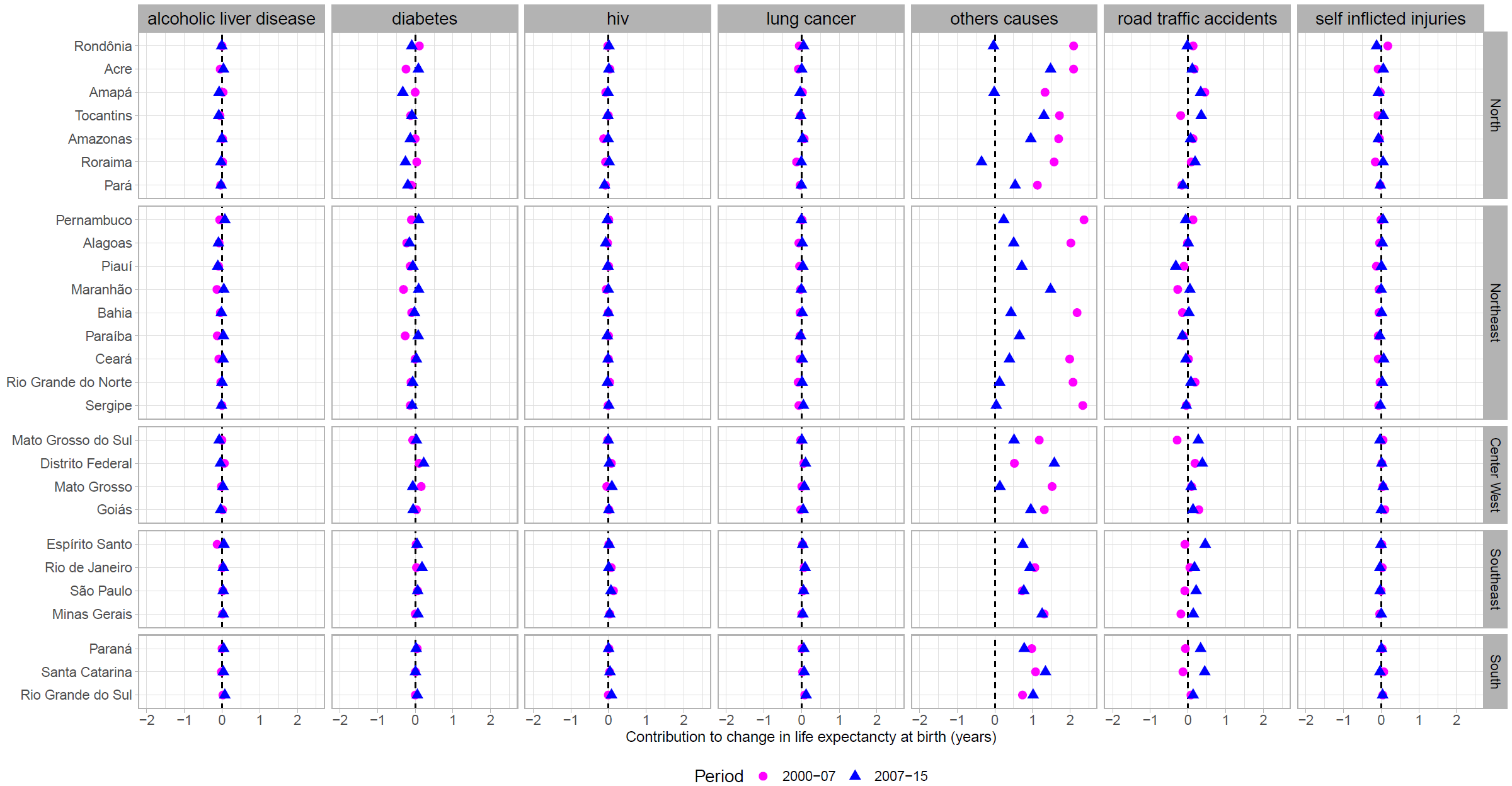
**Section 3. Discussion on other causes of death.** The period 2000 and 2007 also saw increases in mortality from IHD, again offsetting rising life expectancy due to improvements in mortality from other medically amenable causes, and again mostly concentrated in states in the Northern regions. Additionally, some Northern states saw increases in diabetes mortality over the same period, primarily affecting females. On the other hand, in the period 2007-15, improvements in mortality from IHD and diabetes led to increases in life expectancy among females and males in most states. The extent of subnational variation in the impact of homicides, IHD and diabetes related mortality on life expectancy at birth, with a considerably higher burden in Northern compared to Southern states, demonstrates the persistence of health inequalities in Brazil.39

Medically amenable mortality contributed significantly to increasing life expectancy throughout the period from 2000 to 2015. Although in two states, Acre and Maranhão, mortality from amenable causes of death deteriorated between 2000 and 2007, these states recovered and improved life expectancy by reducing mortality attributable to medically amenable causes in 2007-15. Our results mirror findings reported in similar studies. Previous evidence suggests that improvements in primary health care has played an essential role in reducing deaths amenable to health care in Brazil.14 39 Similarly, our study highlights the importance of building a strong healthcare system in the Northern regions to further reduce IHD-related mortality. Comprehensive and community-based health interventions can contribute to further decrease mortality from IHD in areas with high prevalence, such as Northern states of Brazil, through a combination of measures focused on prevention, health care, and follow-up for heart diseases.32

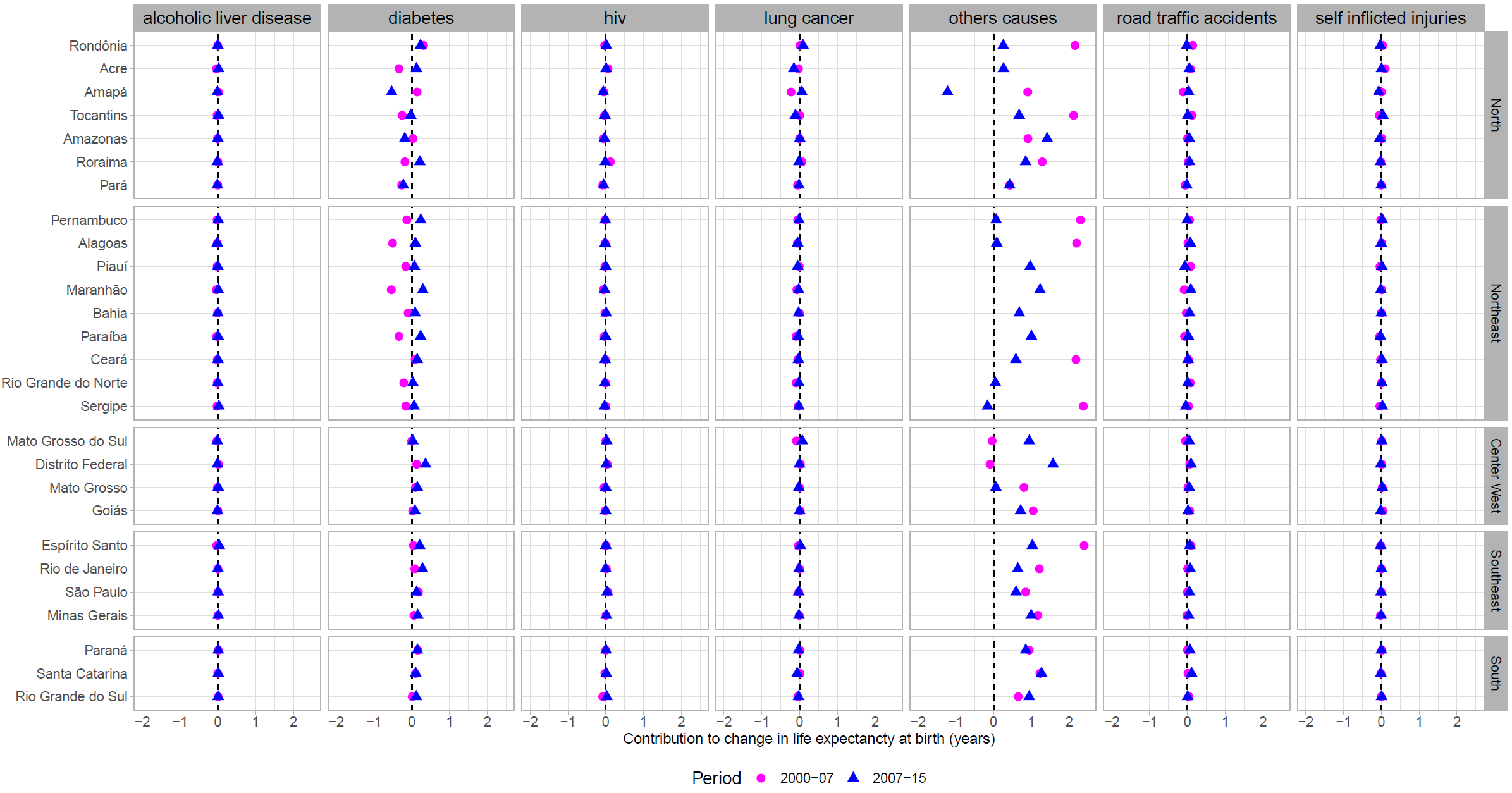
**Figure S1. Map of states in Brazil.**



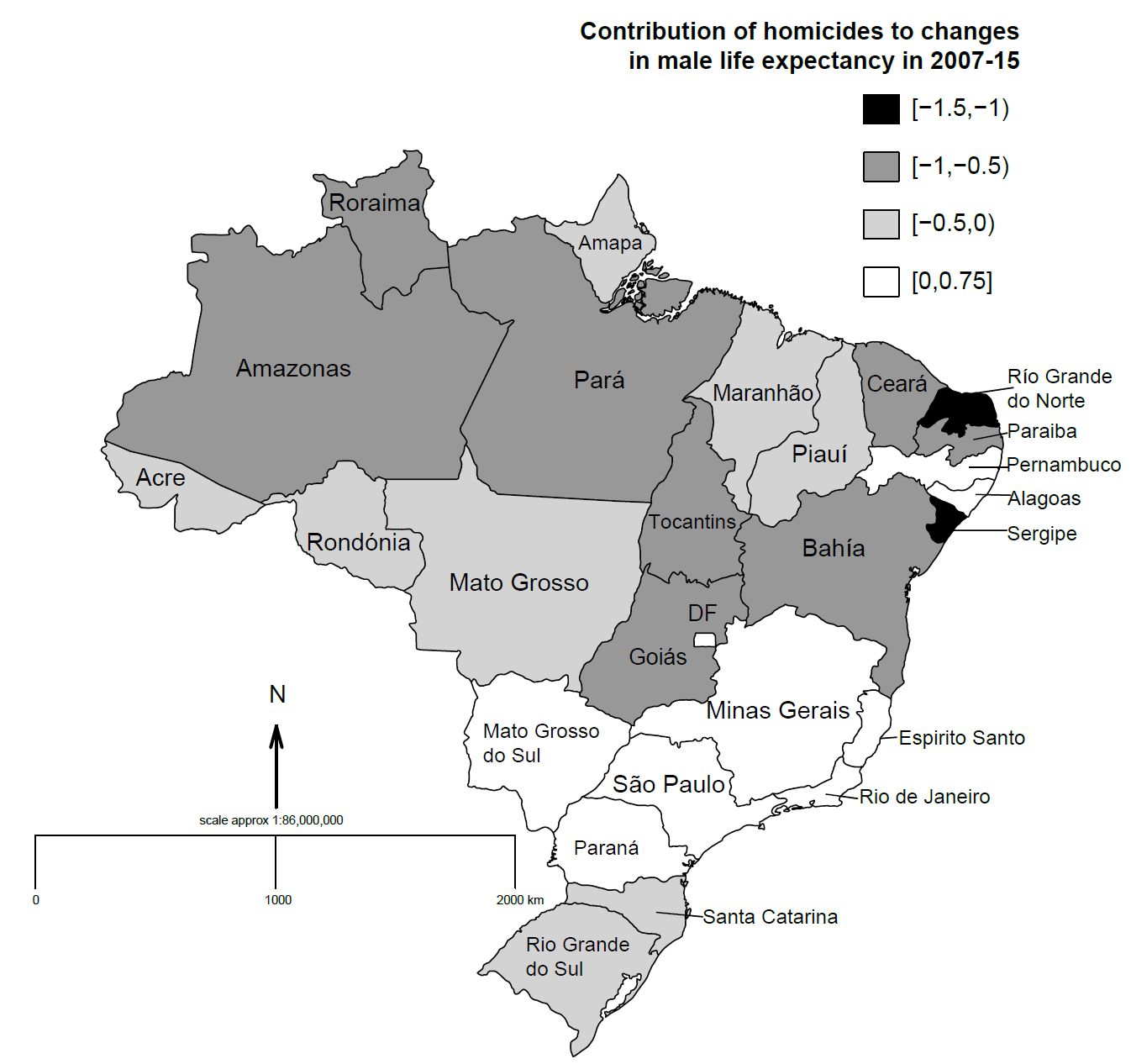
**Figure S2. Cause specific contributions to changes in male life expectancy by state in Brazil.**



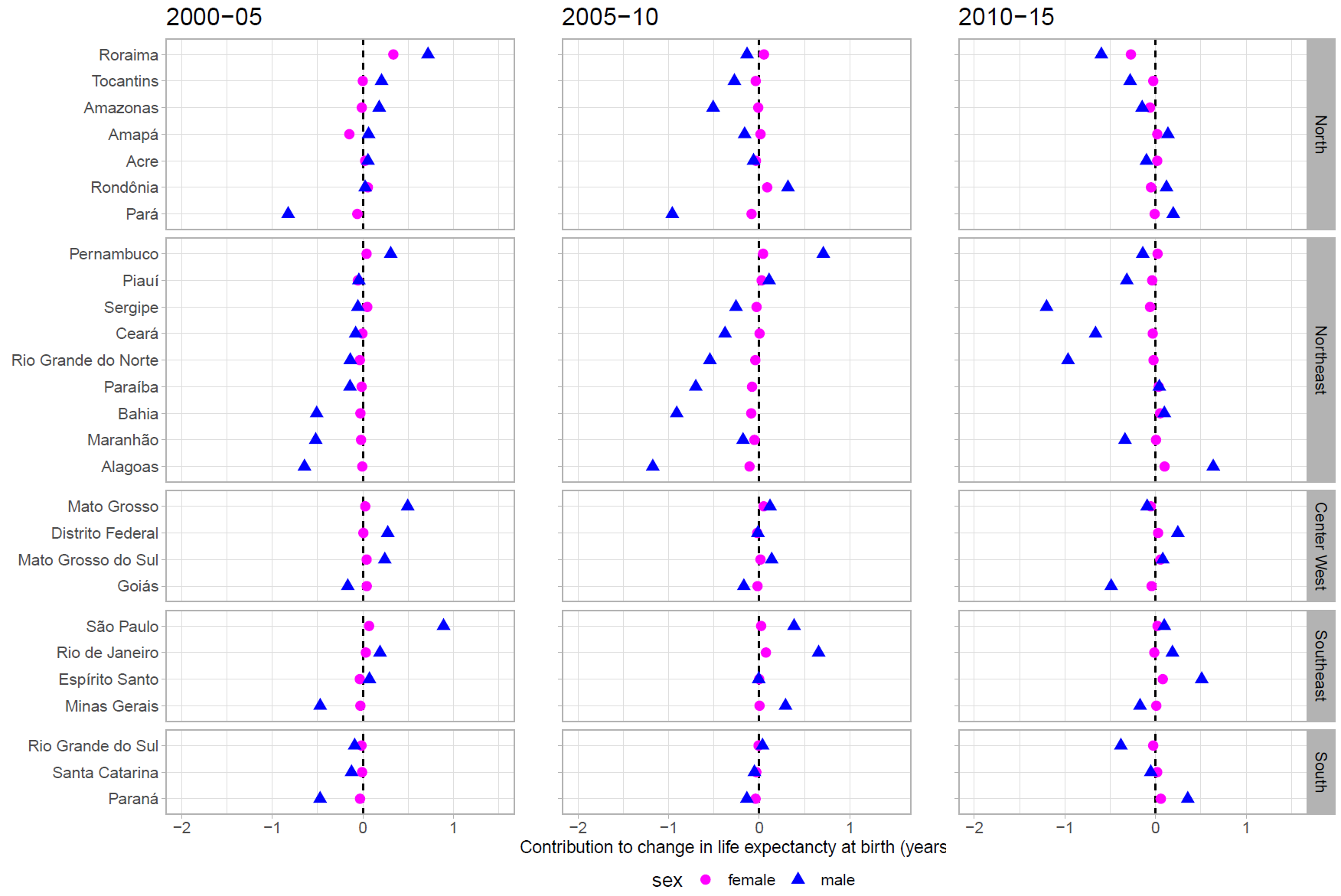
**Figure S3. Cause specific contributions to changes in female life expectancy by state in Brazil.**



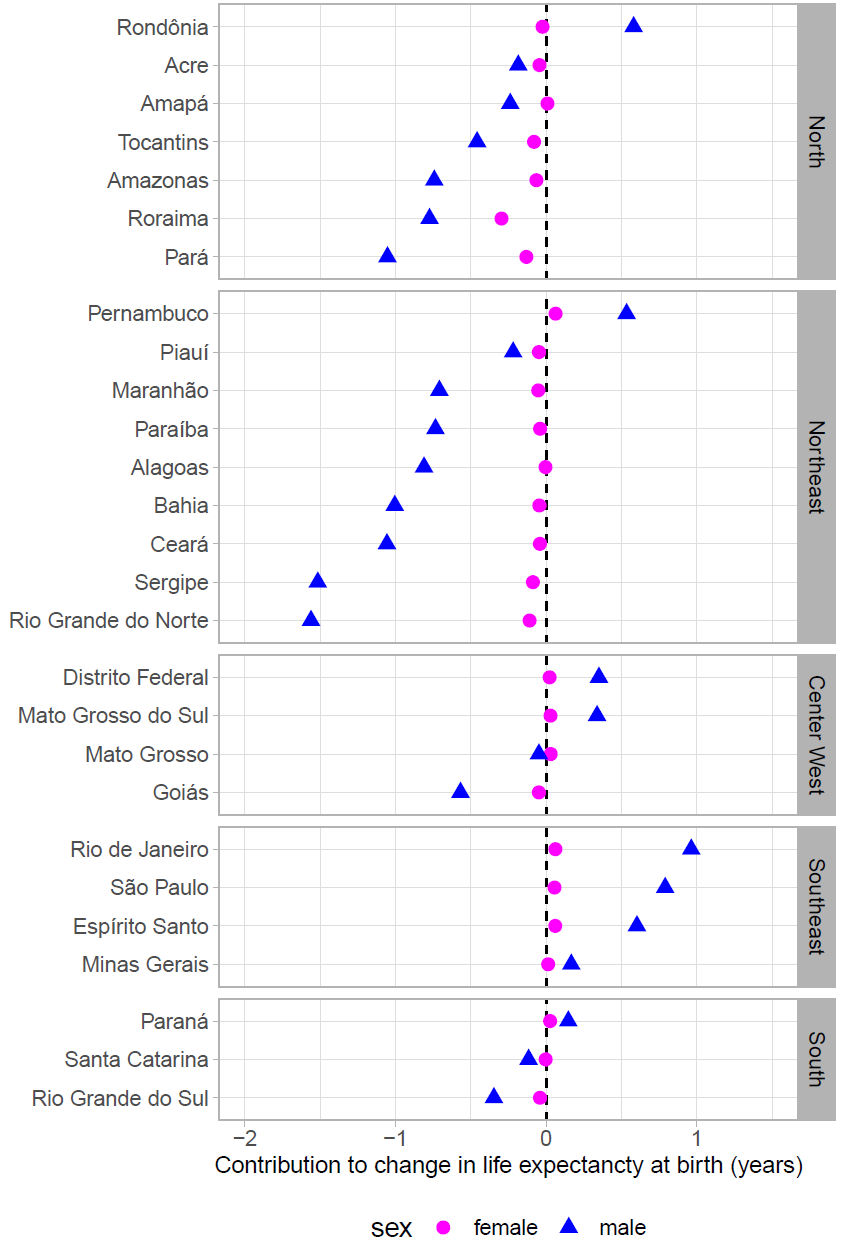
**Figure S4. Homicide contributions to changes in male life expectancy by state in Brazil in 2007-15.**



**Figure S5 Homicide contributions to changes in life expectancy taking different time periods: 2000-05, 2005-10 and 2010-15.**



**Figure S6. Effect of homicides to life expectancy between 2004-15**



**Appendix Table 1. ICD Codes for the classification of avoidable/amenable mortality**

|  |  |  |
| --- | --- | --- |
| Cause | code | descrition |
| Homicide | X85 | Assault by drugs, medicaments, and biological substances |
| X86 | Assault by corrosive substance |
| X87 | Assault by pesticides |
| X88 | Assault by gases and vapors |
| X89 | Assault by other specified chemicals and noxious substances |
| X90 | Assault by unspecified chemical or noxious substance |
| X91 | Assault by hanging, strangulation, and suffocation |
| X92 | Assault by drowning and submersion |
| X93 | Assault by handgun discharge |
| X94 | Assault by rifle, shotgun, and larger firearm discharge |
| X95 | Assault by other and unspecified firearm discharge |
| X96 | Assault by explosive material |
| X97 | Assault by smoke, fire, and flames |
| X98 | Assault by steam, hot vapors, and hot objects |
| X99 | Assault by sharp object |
| Y00 | Assault by blunt object |
| Y01 | Assault by pushing from high place |
| Y02 | Assault by pushing or placing victim before moving object |
| Y03 | Assault by crashing of motor vehicle |
| Y04 | Assault by bodily force |
| Y05 | Sexual assault by bodily force |
| Y06 | Neglect and abandonment |
| Y07 | Other maltreatment syndromes |
| Y08 | Assault by other specified means |
| Y09 | Assault by unspecified means |
| Suicide and self-inflicted injuries | X60 | Intentional self-poisoning by and exposure to nonopioid analgesics, antipyretics, and antirheumatics |
| X61 | Intentional self-poisoning by and exposure to antiepileptic, sedative-hypnotic, antiparkinsonism, and psychotropic drugs, not elsewhere classified |
| X62 | Intentional self-poisoning by and exposure to narcotics and psychodysleptics [hallucinogens], not elsewhere classified |
| X63 | Intentional self-poisoning by and exposure to other drugs acting on the autonomic nervous system |
| X64 | Intentional self-poisoning by and exposure to other and unspecified drugs, medicaments, and biological substances |
| X65 | Intentional self-poisoning by and exposure to alcohol |
| X66 | Intentional self-poisoning by and exposure to organic solvents and halogenated hydrocarbons and their vapors |
| X67 | Intentional self-poisoning by and exposure to other gases and vapors |
| X68 | Intentional self-poisoning by and exposure to pesticides |
| X69 | Intentional self-poisoning by and exposure to other and unspecified chemicals and noxious substances |
| X70 | Intentional self harm by hanging, strangulation, and suffocation |
| X71 | Intentional self harm by drowning and submersion |
| X72 | Intentional self harm by handgun discharge |
| X73 | Intentional self harm by rifle, shotgun, and larger firearm discharge |
| X74 | Intentional self harm by other and unspecified firearm discharge |
| X75 | Intentional self harm by explosive material |
| X76 | Intentional self harm by smoke, fire, and flames |
| X77 | Intentional self harm by steam, hot vapors, and hot objects |
| X78 | Intentional self harm by sharp object |
| X79 | Intentional self harm by blunt object |
| X80 | Intentional self harm by jumping from a high place |
| X81 | Intentional self harm by jumping or lying before moving object |
| X82 | Intentional self harm by crashing of motor vehicle |
| X83 | Intentional self harm by other specified means |
| X84 | Intentional self harm by unspecified means |
| HIV/AIDS | B20 | Human immunodeficiency virus [HIV] disease resulting in infectious and parasitic diseases |
| B21 | Human immunodeficiency virus [HIV] disease resulting in malignant neoplasms |
| B22 | Human immunodeficiency virus [HIV] disease resulting in other specified diseases |
| B23 | Human immunodeficiency virus [HIV] disease resulting in other conditions |
| B24 | Unspecified human immunodeficiency virus [HIV] disease |
| Ischemic heart diseases | I20 | Angina pectoris |
| I21 | Acute myocardial infarction |
| I22 | Subsequent ST elevation (STEMI) and non-ST elevation (NSTEMI) myocardial infarction |
| I23 | Certain current complications following ST elevation (STEMI) and non-ST elevation (NSTEMI) myocardial infarction |
| I24 | Other acute ischemic heart diseases |
| I25 | Chronic ischemic heart disease |
| Lung cancer | C34 | Malignant neoplasm of bronchus and lung |
| Diabetes | E10 | Insulin-dependent diabetes mellitus |
| E11 | Noninsulin-dependent diabetes mellitus |
| E12 | Malnutrition-related diabetes mellitus |
| E13 | Other specified diabetes mellitus |
| E14 | Unspecified diabetes mellitus |
| Road traffic acidentes | V00-V09 | Pedestrian injured in transport accident |
| V10-V19 | Pedal cycle rider injured in transport accident |
| V20-V29 | Motorcycle rider injured in transport accident |
| V30-V39 | Occupant of three-wheeled motor vehicle injured in transport accident |
| V40-V49 | Car occupant injured in transport accident |
| V50-V59 | Occupant of pick-up truck or van injured in transport accident |
| V60-V69 | Occupant of heavy transport vehicle injured in transport accident |
| V70-V79 | Bus occupant injured in transport accident |
| V80-V89 | Other land transport accidents |
| Alcoholic liver disease | K70 | Alcoholic liver disease |
| Avoidable causes of deaths due to interventions of the Brazilian Health System |  | See Malta et al (2007) and Malta et al. (2010) |

Appendix Table 2. Life expectancy estimates for Brazilian states.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Females** | | | |  | **Males** | | | |
| **Region** | **State** | **2000** | **2007** | **2015** | **Increase 2000-15** |  | **2000** | **2007** | **2015** | **Increase 2000-15** |
| Center West | Distrito Federal | 76.4 | 78.2 | 81.3 | 4.9 |  | 68.0 | 71.1 | 74.7 | 6.7 |
|  | Goiás | 73.7 | 75.9 | 77.4 | 3.7 |  | 66.4 | 69.4 | 70.5 | 4.1 |
|  | Mato Grosso | 73.6 | 76.1 | 77.0 | 3.4 |  | 65.3 | 69.1 | 70.7 | 5.4 |
|  | Mato Grosso do Sul | 75.2 | 76.2 | 78.3 | 3.0 |  | 67.8 | 69.6 | 71.8 | 4.0 |
| North | Acre | 72.6 | 74.7 | 75.5 | 2.9 |  | 65.6 | 68.0 | 71.0 | 5.4 |
|  | Amapá | 75.9 | 77.0 | 74.9 | -1.0 |  | 65.5 | 69.1 | 68.5 | 2.9 |
|  | Amazonas | 73.5 | 75.5 | 77.0 | 3.5 |  | 66.7 | 69.8 | 70.3 | 3.6 |
|  | Pará | 75.2 | 74.9 | 75.2 | 0.1 |  | 68.5 | 68.2 | 68.1 | -0.4 |
|  | Rondônia | 71.6 | 76.1 | 77.6 | 6.1 |  | 64.5 | 69.9 | 70.5 | 6.0 |
|  | Roraima | 71.5 | 74.7 | 76.0 | 4.6 |  | 65.7 | 67.9 | 67.0 | 1.3 |
|  | Tocantins | 72.3 | 74.5 | 76.9 | 4.6 |  | 66.8 | 68.9 | 72.3 | 5.5 |
| Northeast | Alagoas | 73.3 | 74.8 | 75.9 | 2.6 |  | 67.2 | 67.0 | 68.7 | 1.5 |
|  | Bahia | 73.3 | 76.7 | 78.7 | 5.3 |  | 68.4 | 70.4 | 71.2 | 2.8 |
|  | Ceará | 73.5 | 76.8 | 78.6 | 5.1 |  | 67.8 | 70.2 | 70.7 | 2.8 |
|  | Maranhão | 71.5 | 73.3 | 76.2 | 4.7 |  | 66.5 | 67.8 | 70.8 | 4.3 |
|  | Paraíba | 73.4 | 76.2 | 78.2 | 4.8 |  | 65.8 | 69.4 | 70.7 | 4.9 |
|  | Pernambuco | 72.9 | 75.7 | 76.9 | 4.0 |  | 63.9 | 67.5 | 69.3 | 5.4 |
|  | Piauí | 71.4 | 75.4 | 77.8 | 6.4 |  | 65.4 | 69.1 | 70.5 | 5.1 |
|  | Rio Grande do Norte | 74.4 | 77.7 | 78.5 | 4.1 |  | 68.5 | 71.0 | 71.4 | 2.9 |
|  | Sergipe | 73.9 | 76.8 | 76.7 | 2.8 |  | 67.2 | 70.0 | 68.7 | 1.4 |
| South | Paraná | 74.1 | 77.0 | 79.0 | 4.9 |  | 67.6 | 70.0 | 72.4 | 4.8 |
|  | Rio Grande do Sul | 76.0 | 77.8 | 79.7 | 3.8 |  | 67.9 | 70.2 | 72.7 | 4.8 |
|  | Santa Catarina | 75.9 | 78.4 | 80.4 | 4.5 |  | 68.9 | 71.1 | 73.8 | 4.9 |
| Southeast | Espírito Santo | 74.5 | 77.4 | 80.3 | 5.7 |  | 66.5 | 69.5 | 72.8 | 6.3 |
|  | Minas Gerais | 74.7 | 77.3 | 79.6 | 4.8 |  | 67.7 | 70.2 | 73.1 | 5.4 |
|  | Rio de Janeiro | 73.9 | 76.3 | 77.6 | 3.8 |  | 64.8 | 67.5 | 70.5 | 5.7 |
|  | São Paulo | 75.4 | 78.0 | 79.3 | 3.9 |  | 66.9 | 70.8 | 72.8 | 5.9 |