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 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 et al. (2016) shows the application of DDM as part of the procedures of the Global Burden of Diseases and Lima and Queiroz (2014) 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 f (e.g. $e^{\dagger}$ or life expectancy) is a differentiable function of n covariates (e.g. each age-cause specific mortality rate) denoted by the vector $\boldsymbol{A} = [x_1, x_2, \dots, x_n]^T$. Assume that f and $\boldsymbol{A}$ depend on the underlying dimension t, which is time in this case, and that we have observations available in two time points t_1 and t_2. Assuming that $\boldsymbol{A}$ is a differentiable function of t between t_1 and t_2, the difference in f between t_1 and $t_2$can be expressed as follows:

$$f_2 - f_1 = \sum_{i=1}^{n} \int_{x_i(t_1)}^{x_i(t_2)} \frac{\partial f}{\partial x_i} dx_i = \sum_{i=1}^{n} c_i, \qquad (2)$$

where c_i is the total change in f (e.g. $e^{\dagger}$ or life expectancy) produced by changes in the i-th covariate, x_i. The c_i'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.

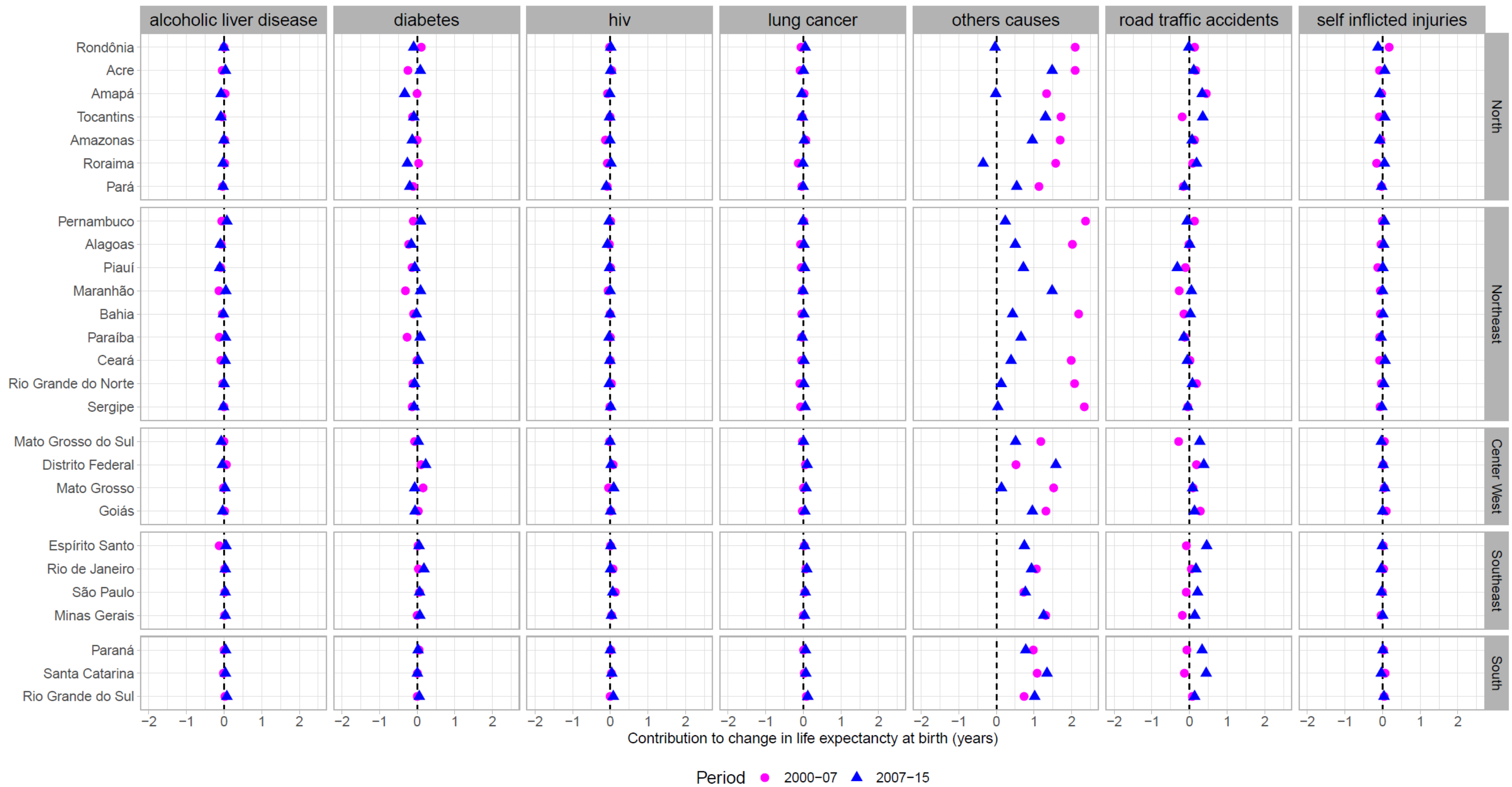


Figure S3. Cause specific contributions to changes in female life expectancy by state in Brazil.

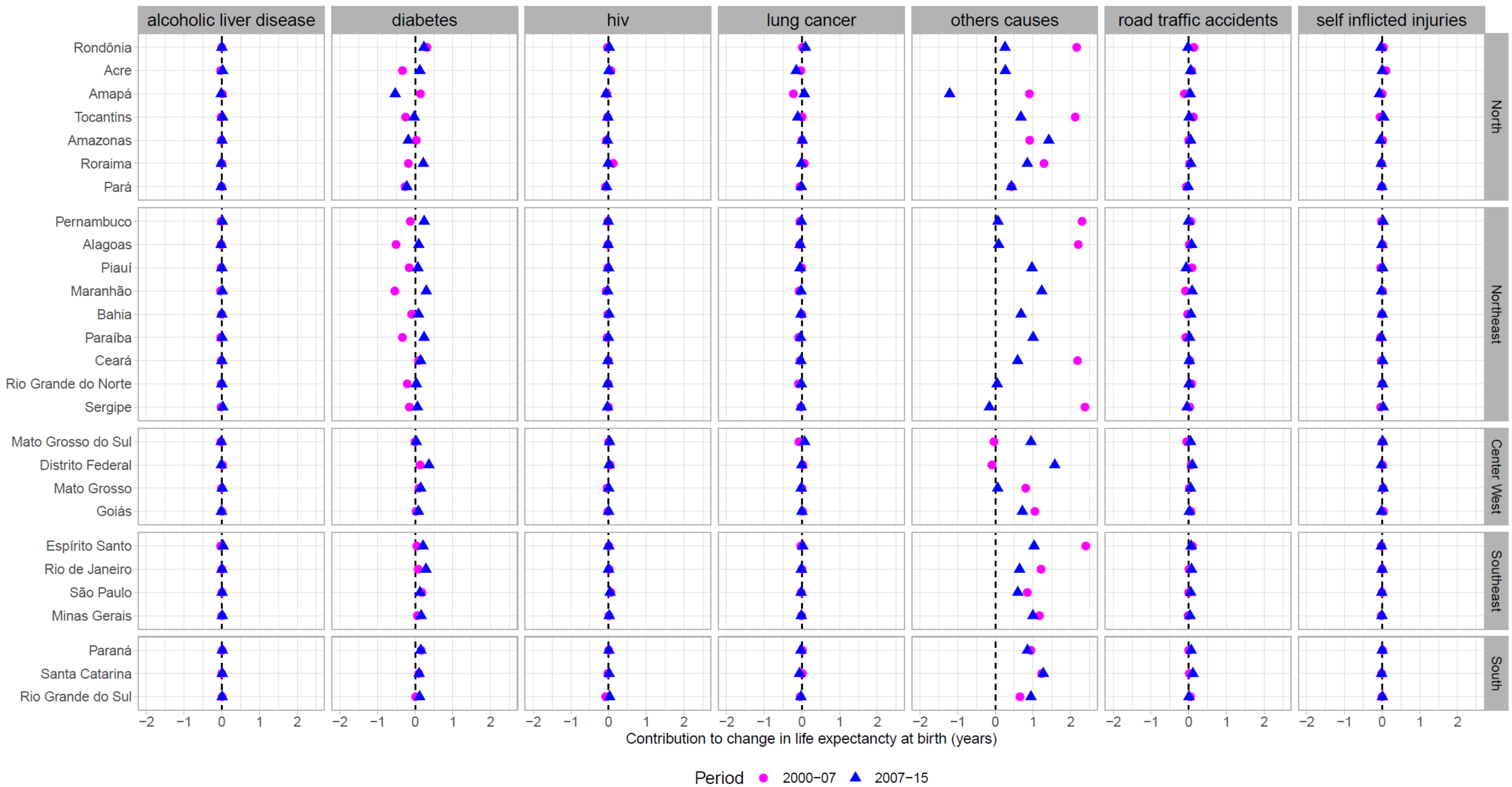


Figure S4. Homicide contributions to changes in male life expectancy by state in Brazil in 2007-15.

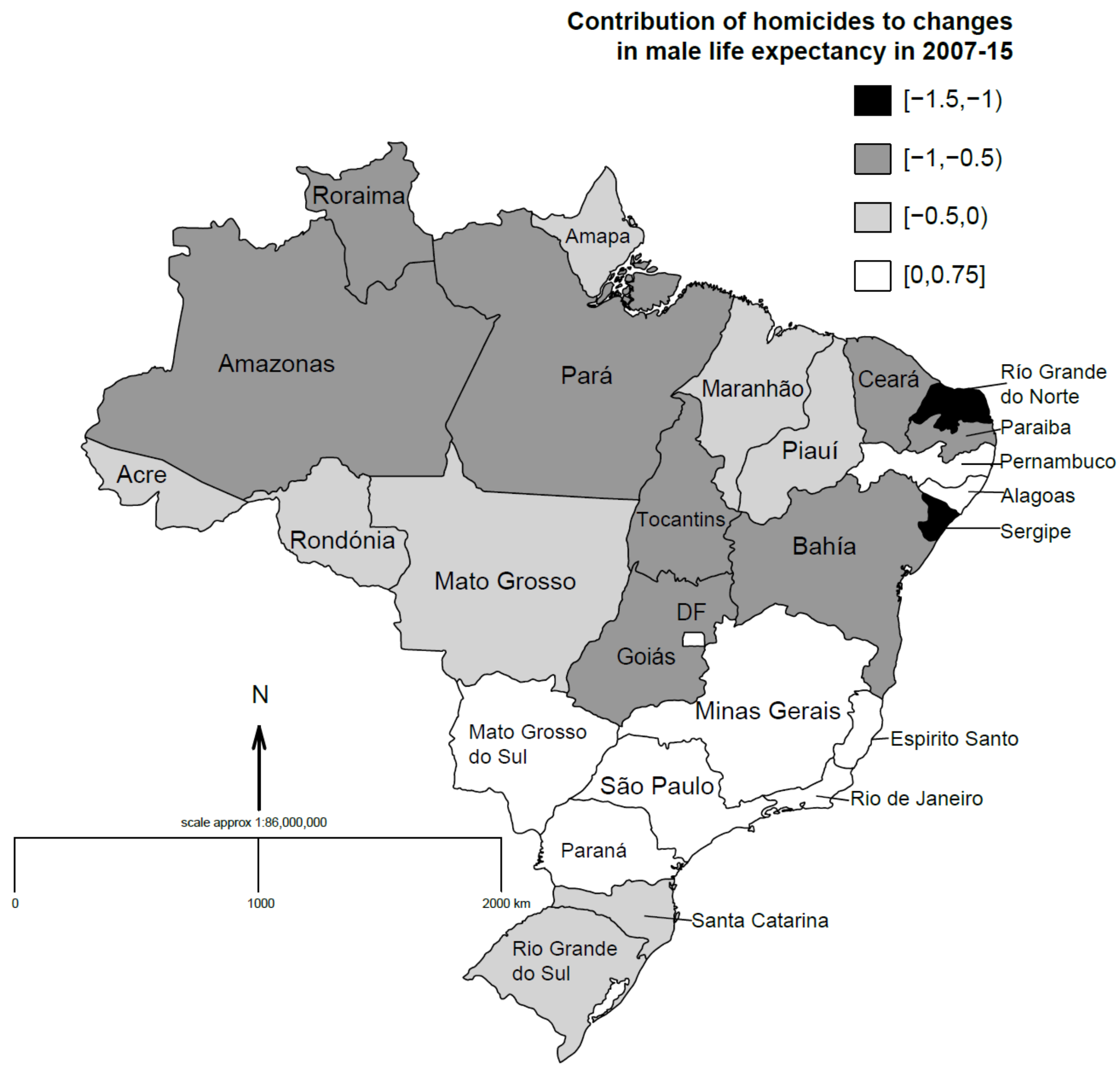


Figure S5 Homicide contributions to changes in life expectancy taking different time periods: 2000-05, 2005-10 and 2010-15.

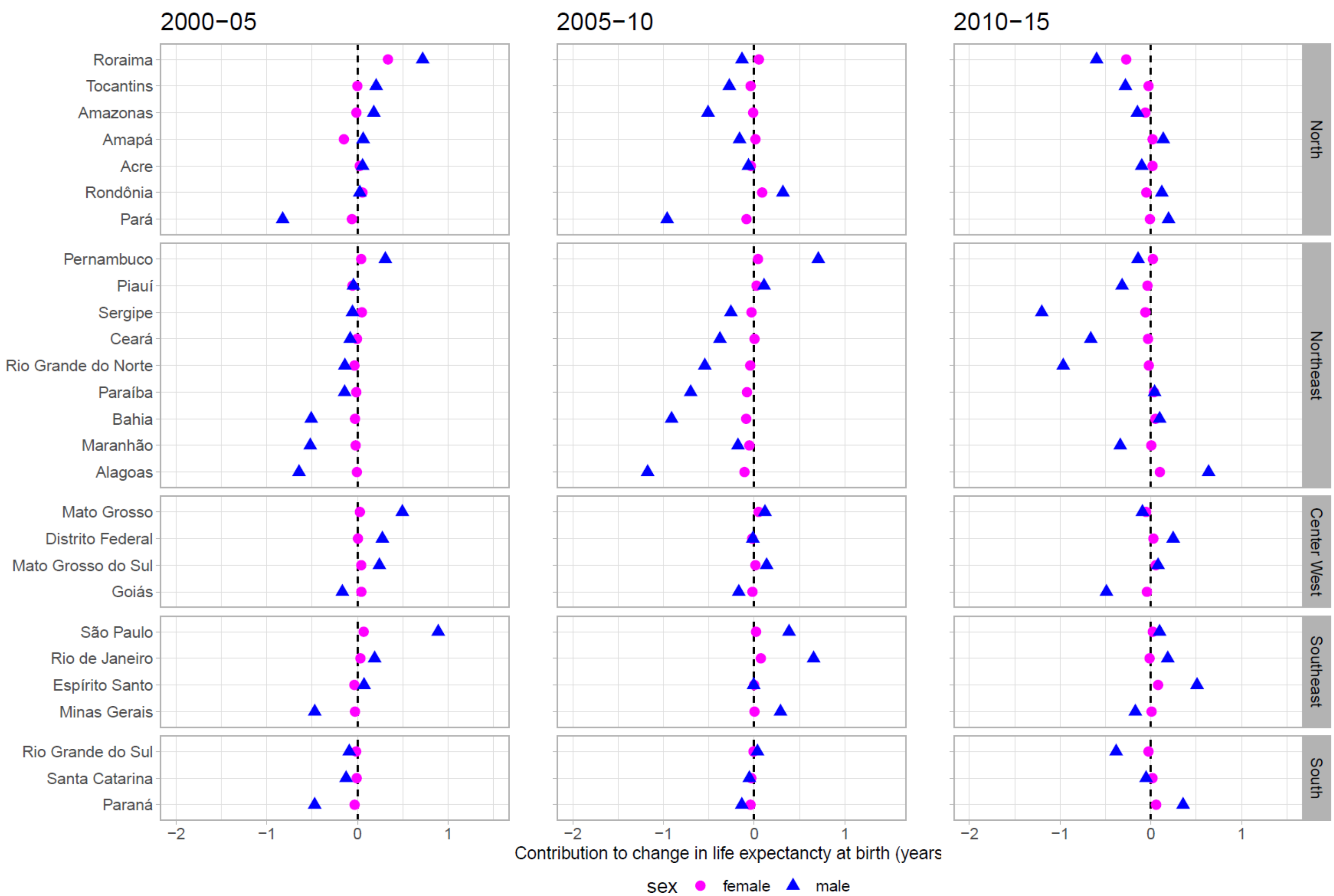
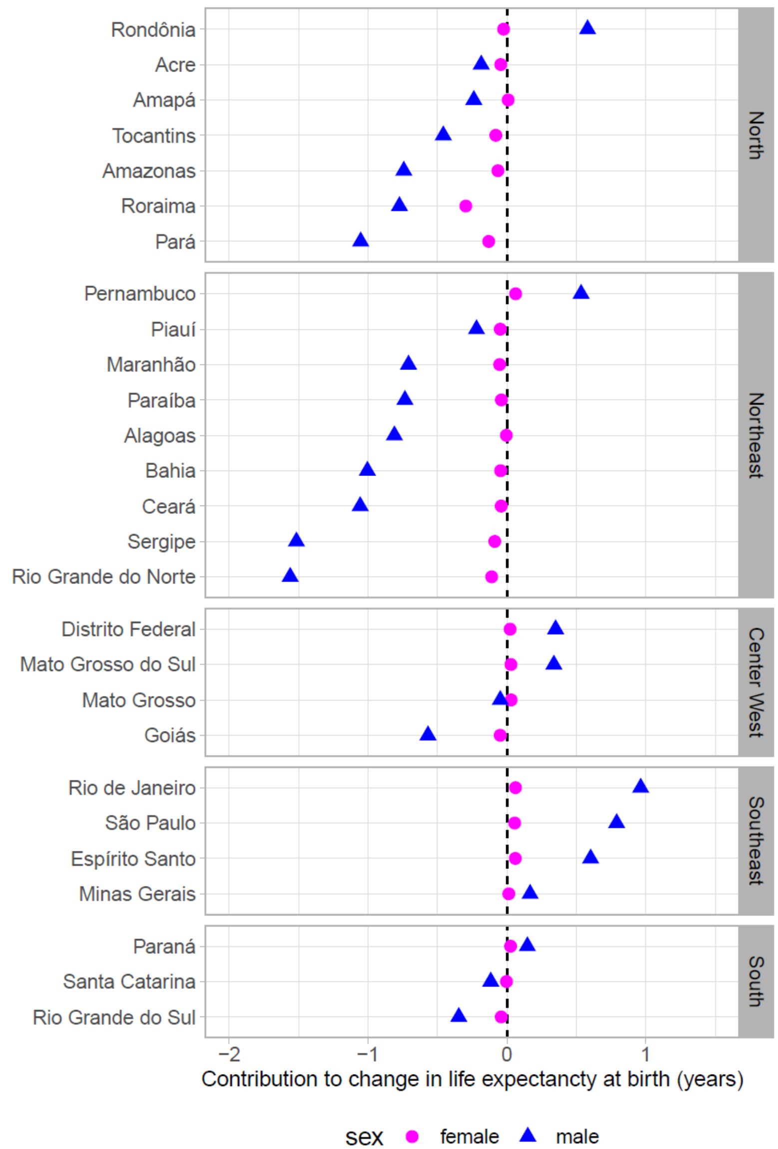


Figure S6. Effect of homicides to life expectancy between 2004-15



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