Age- and Cause-Decomposition of the Difference in Life-Expectancy in Latin American and Caribbean Countries: Data Sources and Methodology.

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The aim of this work is to carry out age- and cause-specific decompositions of differences in life-expectancy over time for Latin American and Caribbean (LAC) countries. The time of analysis is the period from 1990 to the most recent available year of mortality information. A second element of this comparison is for each LAC country with a group of European countries, denoted EU-15.

Based on population size and available mortality information 23 countries were selected. In the Caribbean 6 countries: Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, and Trinidad and Tobago; In Central America 7 countries: Costa Rica, El Salvador, Guatemala, Honduras, México, Nicaragua, and Panamá; In South America 10 countries: Argentina, Bolivia, Brasil, Chile, Colombia, Ecuador, Paraguay, Perú, Uruguay, and Venezuela. Table 1 lists the population sizes and the years with cause of death information for all selected countries.

[Table 1 about here]

Sources of data

Two larger sources of data were needed in order to decompose the effects of different diseases on life expectancy changes: cause specific mortality data and life table data.

Cause of death information was taken from the World Health Organization mortality database (WHO), which has cause specific mortality rates over time for most countries. In order to increase observations and ensure comparability across countries, we used the same initial year of cause of death data for all countries, namely 1990, but allowed each country to have as last year its year with the most recent cause of death information. All LAC countries reported cause of death data using the International Classification of

Diseases revisions 9 and 10, or ICD-9 and ICD-10 codes, for the analyzed period. Cause of death information was collected from this source for ages 0, 1-4, and then in five-year age groups until the open age-group which varied from country to country to be 80 and more, 85 and more, or 95 and more. Although, this could be thought as problematic, the great share of the changes in life expectancy in the region still happen at ages below 80. Thus, the main results are not affected by decisions made on the last age-interval. There was much greater variation in the years with available information in the LAC region. For example, Haiti only had causes of death information for the years 1997, 1999, and 2001-04, while Cuba had information for every single year from 1990 to 2014 (see Table 1). Also in Table 1 the WHO-code for each country is included, which we used to identify the data for each country in the data archive repository (see accompanying folders for causes of death data: CoDdata; and for life table information: LifeTableData).

Seventeen causes of death were selected corresponding to the mayor ICD chapters and one for the remaining causes not included among the 17, denoted “other causes”. The list of causes of death and their corresponding ICD-10 code is: (A00-B99) Certain infectious and parasitic diseases, (C00-D48) Neoplasms, (E00-E88) Endocrine, nutritional and metabolic diseases, (F01-F99) Mental and behavioural disorders, (G00-G98) Diseases of the nervous system, (I00-I99) Diseases of the circulatory system, (J00-J98) Diseases of the respiratory system, (K00-K92) Diseases of the digestive system, (N00-N98) Diseases of the genitourinary system, (P00-P96) Perinatal & (Q00-Q99) Congenital malformations, (R00-R99) Not elsewhere classified, (V01-Y89) Accidents and suicide, and (X85-Y09) Homicide. The year of the change of ICD code from 9 to 10 was different from country to country and it is found as a vertical dashed line in each country page in the interactive link-app:

https://wb-lac.shinyapps.io/CoD_App/

The above interactive link-app has a left dropdown menu which allows user to select among the different LAC countries to visualize the time trends of the causes of death by sex.

No significant ruptures from ICD-9 to ICD-10 codes were observed for any of the countries. However, Figure 1a and 1b show the contrasting results of the causes of death time trends for a country with uninterrupted annual data from 1990 to 2014 as Costa Rica, as opposed to Honduras where only one point is available in 1990 and then continuously from 2008 to 2013 (thus the linear trend from 1990 to 2008).

[Figures 1a and 1b about here]

Life table data were taken from a variety of sources with preference given to those reporting by sex and grouped in five calendar years, as to avoid the year to year random fluctuations. These included the UN demographic yearbooks, and the estimates from the Comisión Económica para América Latina y el Caribe (CEPAL, Economic Commission for Latin America and the Caribbean) for 2004 and 2010 (referred as CEPAL 2004 and CEPAL 2010 respectively). Other sources of life table collections used as comparison were Lambda (Latin America Mortality Database), and life tables elaborated at each of the national statistical offices (CEPAL has made a list of these statistical offices: http://www.cepal.org/es/temas/censos-de-poblacion-y-vivienda/enlaces-institutos-nacionales-estadistica-america-latina-caribe). The disparity between the sources varies from country to country, as can be observed in the different estimates of time trends in life expectancy at birth for females and males in the interactive link-app:

https://wb-lac.shinyapps.io/ex_App/

The above interactive link-app has a left dropdown menu which allows user to select among the different LAC countries to visualize the time trends of the life expectancy at birth by sex.

Figure 2a and 2b show time trends of the female and male life expectancy at birth for Honduras and Mexico respectively. While Figure 2a shows very coherent time trends among the different life table sources for Honduras, there is no matching in the Mexican trends. Furthermore, for the latter country, CEPAL and UN show overall increases in the measure in the first decade of the new millennium, 2000-2010, while researchers have documented the stagnation in the measure, particularly for males (Canudas-Romo et al.

2015; Aburto et al. 2016), also observed in the data published by the National Statistical Office. This shows that even when the same data is used for the life table calculations, resultant estimates in the region might differ and have to be studied with caution.

[Figures 2a and 2b about here]

In order to maximize comparability in the age and cause decomposition (summarized in the next section), life tables from CEPAL and UN were selected for years that had WHO cause of death information. Life tables were selected for the following periods: 1990-1994, 1995-1999, 2000-2004, 2005-2009 and 2010-2014 (or latest available year). Causes of death were also organized in these five calendar years. We were able to match life table and cause of death data for the same years for most countries.

Methodology

Age-Decomposition of Differences in Life Expectancies at Birth

The age- and cause-decomposition of the difference in life expectancies derive from the formulations of Arriaga (1984) and the simple exposition of the topic by Preston et al. (2001).

Differences in life expectancy at birth between two times, e_0^2 and e_0^1, can be written as the sum of the age-specific contributions as

$$e_0^2 - e_0^1 = \sum_x \Delta_x \,, \tag{1.1}$$

where Δ_x is the age-specific contribution to this difference. The age-specific contributions in equation (1.1) are derived from the life table functions: survivors at age *x*, ℓ_x, person-years lived in the interval *x* to *x+1*, L_x, and person-years lived after age *x*, T_x, for the two given times:

$$\Delta_x = \left(\frac{\ell_x^1}{\ell_0^1}\right)\left(\frac{L_x^2}{\ell_x^2} - \frac{L_x^1}{\ell_x^1}\right) + \left(\frac{T_{x+1}^2}{\ell_0^1}\right)\left(\frac{\ell_x^1}{\ell_x^2} - \frac{\ell_{x+1}^1}{\ell_{x+1}^2}\right) \quad . \tag{1.2}$$

Cause-Decomposition of Difference in Life Expectancies at Birth

The difference in life expectancy at birth between two populations can be further decomposed by causes of death, that is, we can estimate the contribution of the total difference in life expectancy attributable to specific causes of death by age.

In order to estimate cause specific mortality contributions we partition the age-specific contribution, Δ_x, into the part that corresponds to each of the causes of death *i* of interest, or Δ_x^i.

Assuming that there are *n* independent causes of death we calculate the cause *i* contribution based on a set of all cause age-specific mortality rates and the proportions of deaths at each age attributable to cause of death *i*:

m_x^1 = all-cause mortality rate at age *x* and time *1*

$R_{x,i}^1$ = proportion of deaths from cause *i*, at age *x* and time *1*,

A similar set of information is needed for time *2*. All the above information is combined to calculate the age- and cause-contribution to the difference in life expectancy as

$$\Delta_{x,i} = \frac{R_{x,i}^2\ m_x^2 - R_{x,i}^1\ m_x^1}{m_x^2 - m_x^1}. \tag{1.3}$$

Multiplying the previously derived mortality contribution for each age, Δ_x, with the addition over all causes of the age- and cause-contribution in equation (1.3) returns the desired difference in life expectancy at birth due to changes in age-specific and cause-specific mortality:

$$e_0^2 - e_0^1 = \sum_x \Delta_x \left(\sum_i \Delta_{x,i} \right). \quad (1.4)$$

The results of the age- and cause-decomposition are presented for each country in the interactive link-app:

https://wb-lac.shinyapps.io/Decomp_App/

The above interactive link-app has several left dropdown menus which allow user to select among the different LAC countries, sex, period of interest, and source of information. There are also four different options found on the upper horizontal menu listed here and explained below: *"Decomposition by age and cause of death", "Cause-specific contribution", "Comparison with EU-15"* and *"Cause-specific contributions vs EU-15"*.

"Decomposition by age and cause of death" includes the age- and cause-decomposition to the change over time in life expectancy at birth. For example Figures 3a and 3b show the female life expectancy decomposition for Peru and Panama respectively. Values are classified as contributing positively or negatively (above or below the value of zero in the vertical axis) corresponding to contributions to the increase or decrease in life expectancy at birth. For each age the value in a box above the age-axis indicates the contribution of that age-group to the change in life expectancy. This value is further disentangled into causes of death, shown in the Figures with different colors. While the Peruvian comparison is dominated by almost half of the deaths in the category of ill defined - Not elsewhere classified causes (colored in gray), in the case of Panama it is possible to appreciate clearly the vast contribution of cardiovascular diseases to the increase in life expectancy at ages above 45.

[Figures 3a and 3b about here]

"Cause-specific contribution" is the second page in the interactive link-app and allows the user to obtain the cause-specific contribution to the difference in life

expectancies between ages zero and 79. The age restriction was selected to avoid problematic cause of death data found in the oldest age-groups 80 and more. As noted earlier this limitation is minor since most of the changes in life expectancy in the region are due to mortality changes below age 80. Furthermore, these Tables include a total of 13 causes of death as opposed to 9 in the Figures of "*Decomposition by age and cause of death*", thus allowing a much greater detail. For example, Tables 2a and 2b show the cause-contribution to the change in male life expectancy in Ecuador from 1990-94 to 1995-1999. While Table 2a is ordered alphabetically by ICD chapters, Table 2b is ordered from highest to lowest contribution to the change in life expectancy. This switch in order (available at a small arrow next to the word "*Contribution*") allows to rapidly visualizing how neoplasms, respiratory diseases, and mental disorders are the main contributors to the increase in life expectancy, and opposing this trend is the negative value in homicides.

[Tables 2a and 2b about here]

"*Comparison with EU-15"* presents the life expectancy decomposition between LAC countries (based on UN data) and the group of EU-15 countries in 2010-14. Although the calculations presented in equations (1.1) to (1.4) refer to changes in life expectancies over time, analogous operations can be used for the comparison of two populations in one given time. For example, our interest might be to study which ages and causes of death help explain the difference in male life expectancies at birth between Venezuela and EU-15. In this case e_0^1 will correspond to the male life expectancy in Venezuela (e_0^1=70.66), and e_0^2 the EU-15 life expectancy (e_0^2 = 80.24), both in 2010-2014, similarly for other life table functions in equations (1.1) to (1.4). The interactive link-app allows the user to compare the different LAC countries by sex to their EU-15 counterparts in 2010-2014.

Details of the EU-15 countries included in the analysis are found in Table 3. Figure 4a presents the male life expectancy comparison of the EU-15 and Venezuela in 2010-2014. The almost 10 years gap in life expectancy between the two populations highlights the lag in the south American country respect to the EU-15 countries. Here positive contributions are those that help explain the higher life expectancy of EU-15 opposed to

the LAC countries. For Venezuela, while cardiovascular and diabetes (endocrine) mortality explain the old age gap for both females and males, homicides and other external causes (accidents and suicide) further increase the lagging of the Latin American male population. Furthermore, "*Cause-specific contributions vs EU-15*" presents the cause-specific contribution to the difference in life expectancies between ages zero and 79 including a total of 13 causes of death. By ordering the contribution of the causes for the Venezuelan males lag of 9.7 years behind their EU-15 counterpart, it is possible to see that violent deaths, including accidents, homicides and suicide, surpass the contribution of cardiovascular diseases in explaining this gap, with almost 4 years.

[Table 3 and Figures 4a and 4b about here]

EU-15 versus LAC and its subpopulations

To further assess the disparity between the region and its EU-15 counterpart, subpopulations were created based on their rankings of life expectancies. Costa Rica had the maximum life expectancy, average of females and males in 2010-2014, which was used as the benchmark life expectancy to classify the rest of the countries. Four groups were created based on their gap to the Costa Rican life expectancy: high life expectancy (differed by less than 4 years), medium high life expectancy (less than 6 but more than 4 years), medium low life expectancy (less than 8 but more than 6 years) and low life expectancy (more than 8 years). The full list of countries for each of these 4 groups of life expectancies is found in Table 4. The justification of this classification is that levels of the epidemiological transition and the causes of death dynamics hold strong relation with specific levels life expectancy, as shown in the classic works of Preston (1976) and Preston, Keyfitz and Schoen (1972). For example, low levels of life expectancy are related to infectious diseases and high infant and maternal mortality, while low mortality populations suffer of excess cardiovascular and neoplasm mortality. Thus, basing our groupings on the life expectancies will suffice to group countries into "similar" clusters of the epidemiological transition.

[Table 4 about here]

The results of the age- and cause-decomposition of the difference between EU-15 and the LAC region, and sub-regions as classified above, are presented in the interactive link-app:

https://wb-lac.shinyapps.io/Decomp_Ranking_App/

The left menu allows the user to select between the comparison of EU-15 to the *"Total Latin America"*, or to each of the life expectancies groupings (High, Medium high, Medium low and Low), as well as by sex. As in the previous app it is possible to find the Figure as well as a Table summarizing the specific contributions of each of the causes of death. UN data has a life table for the entire region which was used for this comparison. At each age, the cause of death proportions used in equation (1.3) were calculated by adding over all countries the deaths for each cause (using data in Table 1) and dividing by all the deaths at that age. Similar cause of death proportions were elaborated for the EU-15 region and the subregions based on the life expectancy rankings.

All calculations were performed using the R-software programing language and its' shiny-app package, the accompanying folder RCode includes all the programs used as well as the free available data used in this project.

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Table 1. Population and causes of death data in the analyzed period for the 23 included countries

	Major area, region, country or area *	Population, both sexes (1000) 1990	2000	2010	Years with cause of death information (WHO) Country code WHO	starting year	ending year	missing year	or	other available year
	LATIN AMERICA AND THE CARIBBE	446 889	526 890	599 823						
	Caribbean (6 countries)	**34 198**	**38 314**	**41 621**						
1	Cuba	10 582	11 117	11 308	2150	1990	2014			
2	Dominican Republic	7 184	8 563	9 898	2170	1990	2012	1993		
3	Haiti	7 100	8 549	10 000	2270	2001	2004			1997,99
4	Jamaica	2 386	2 600	2 741	2290	2009	2011			1990-91, 2000-06
5	Puerto Rico	3 518	3 797	3 710	2380	1990	2014			
6	Trinidad and Tobago	1 222	1 268	1 328	2440	1990	2010			
	Central America (7 countries)	**114 823**	**138 780**	**161 117**						
7	Costa Rica	3 096	3 925	4 545	2140	1990	2014			
8	El Salvador	5 252	5 812	6 038	2190	1990	2013	1994		
9	Guatemala	9 159	11 689	14 732	2250	2000	2014			
10	Honduras	4 903	6 243	7 504	2280	2008	2013			1990
11	Mexico	85 609	102 809	118 618	2310	1990	2014			
12	Nicaragua	4 145	5 027	5 738	2340	1990	2013	1995		
13	Panama	2 471	3 029	3 621	2350	1996	2014			
	South America (10 countries)	**297 869**	**349 796**	**397 085**						
14	Argentina	32 730	37 057	41 223	2020	1990	2014			
15	Bolivia (Plurinational State of)	6 856	8 340	9 918	2060	2000	2003			
16	Brazil	150 393	175 786	198 614	2070	1990	2014			
17	Chile	13 141	15 170	17 015	2120	1990	2014			
18	Colombia	34 272	40 404	45 918	2130	1990	2013			
19	Ecuador	10 218	12 629	14 935	2180	1990	2014			
20	Paraguay	4 214	5 303	6 210	2360	1994	2014			1990-91
21	Peru	21 827	25 915	29 374	2370	1990	2014	1993		
22	Uruguay	3 110	3 321	3 374	2460	1993	2014	2011		1990
23	Venezuela (Bolivarian Republic of)	19 862	24 481	28 996	2470	1990	2013	1991, 1995		

Source: Population counts from UN database, and cause of death data from WHO database

Table 2a. Cause-contribution to the change in male life expectancy in Ecuador from 1990-94 to 1995-1999. Ordered alphabetically by ICD chapters

Decomposition of life expectancy

Sex: MALES

Country: ECUADOR

Initial period: 1990-1994

Available sources: UN

Period 1: 1990-1994 | Life expectancy: 67.89
Period 2: 1995-1999 | Life expectancy: 69.34
Difference 1.45

Decomposition by age and cause of death | Cause-specific contributions | comparison with EU-15

Search:

Cause	Contribution
a) (A00-B99) Certain infectious and parasitic diseases	0.04
b) (C00-D48) Neoplasms	0.57
c) (E00-E88) Endocrine, nutritional and metabolic diseases	-0.07
d) (F01-F99) Mental and behavioural disorders	0.17
e) (G00-G98) Diseases of the nervous system	0
f) (I00-I99) Diseases of the circulatory system	0.13
g) (K00-K92) Diseases of the digestive system	0.06
h) (J00-J98) Diseases of the respiratory system	0.38
i) (N00-N98) Diseases of the genitourinary system	-0.05
j) (P00-P96) Perinatal & (Q00-Q99) Congenital malformations	0.06
k) (R00-R99) Not elsewhere classified	0
l) (V01-Y89) External mortality: accidents and suicide	0.02
m) (X85-Y09) Homicide	-0.17
n) Rest of causes	0.04
Total	1.18

Showing 1 to 15 of 15 entries
Note: Values represent only the results for ages 0-79. Information for ages 80 and above was omitted as it is problematic data

Table 2b. Cause-contribution to the change in male life expectancy in Ecuador from 1990-94 to 1995-1999. Ordered by relevance in the contribution to the change in life expectancy

Decomposition of life expectancy

Sex: MALES

Country: ECUADOR

Initial period: 1990-1994

Available sources: UN

Period 1: 1990-1994 | Life expectancy: 67.89
Period 2: 1995-1999 | Life expectancy: 69.34
Difference 1.45

Decomposition by age and cause of death | Cause-specific contributions | comparison with EU-15

Search:

Cause	Contribution
Total	1.18
b) (C00-D48) Neoplasms	0.57
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f) (I00-I99) Diseases of the circulatory system	0.13
c) (E00-E88) Endocrine, nutritional and metabolic diseases	-0.07
g) (K00-K92) Diseases of the digestive system	0.06
j) (P00-P96) Perinatal & (Q00-Q99) Congenital malformations	0.06
i) (N00-N98) Diseases of the genitourinary system	-0.05
a) (A00-B99) Certain infectious and parasitic diseases	0.04
n) Rest of causes	0.04
l) (V01-Y89) External mortality: accidents and suicide	0.02
e) (G00-G98) Diseases of the nervous system	0
k) (R00-R99) Not elsewhere classified	0

Showing 1 to 15 of 15 entries
Note: Values represent only the results for ages 0-79. Information for ages 80 and above was omitted as it is problematic data

Table 3. Life table years and sources for EU-15 Countries			
	Country Code WHO	**Year**	**Source**
EU-15			
Austria	4010	2010-14	HMD
Belgium	4020	2010-14	HMD
Denmark	4050	2010-14	HMD
Finland	4070	2010-14	HMD
France	4080	2010-14	HMD
Germany	4085	2010-14	HMD
Greece	4140	2010-14	Eurostat
Ireland	4170	2010-14	HMD
Italy	4180	2010-14	HMD
Luxembourg	4190	2010-14	HMD
Netherlands	4210	2010-14	HMD
Portugal	4240	2010-14	HMD
Spain	4280	2010-14	HMD
Sweden	4290	2010-14	HMD
UK	4308	2010-14	HMD

Source: Human Mortality Database as HMD and Eurostat database

Table 4. Countries in the LAC region classified by their life expectancy gap to the Costa Rican, or maximum life expectancy in 2010-2014

X = Life expectancy gap [Costa Rican – each country]			
High (X < 4)	Medium high (4 ≤ X < 6)	Medium low (6 ≤ X < 8)	Low (8 ≤ X)
Costa Rica	Argentina	Colombia	Guatemala
Cuba	Venezuela	Brazil	Bolivia
Puerto Rico	Ecuador	Dominican Republic	Trinidad y Tobago
Chile	Peru	Honduras	Haiti
Uruguay	Jamaica	El Salvador	
Panama	Nicaragua	Paraguay	
Mexico			

Source: UN and CELADE databases

Figure 1a. Trends over time in the proportions of causes of death, Costa Rica, 1990-2014

Figure 1a. Trends over time in the proportions of causes of death, Honduras, 1990-2013

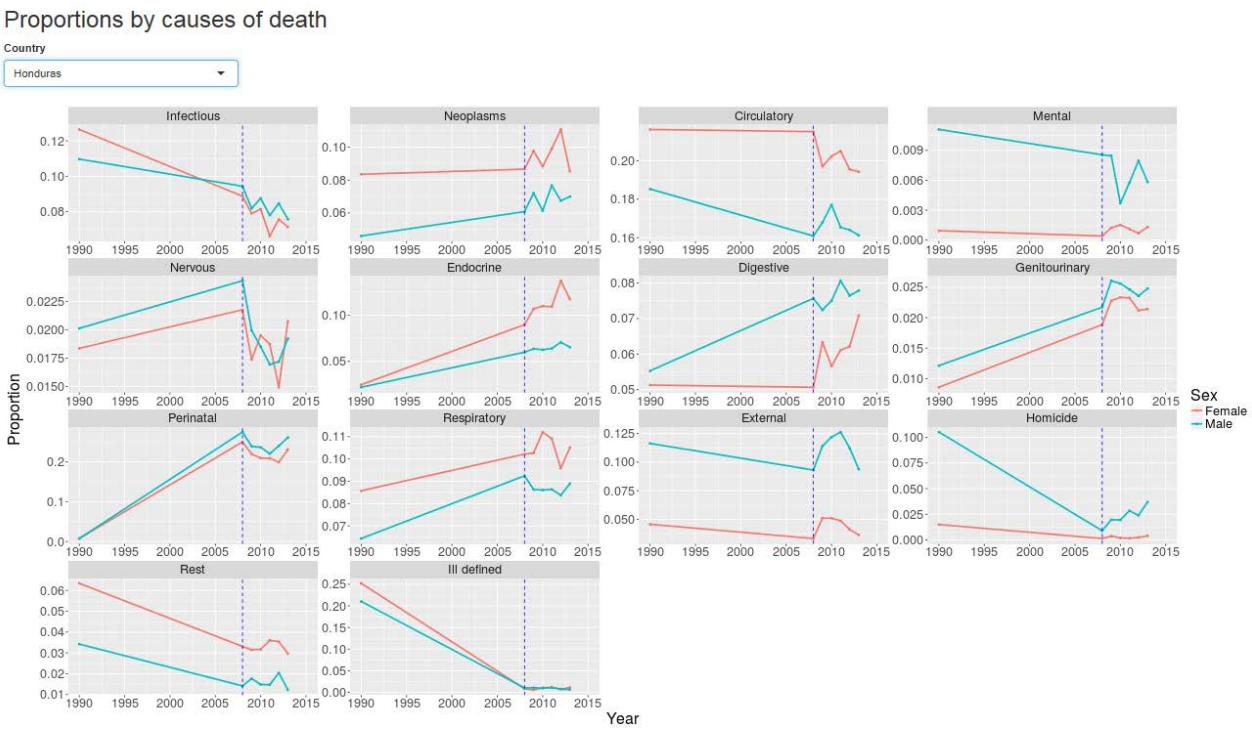

Figure 2a. Trends over time in the life expectancy at birth estimates, Honduras, 1990-2013

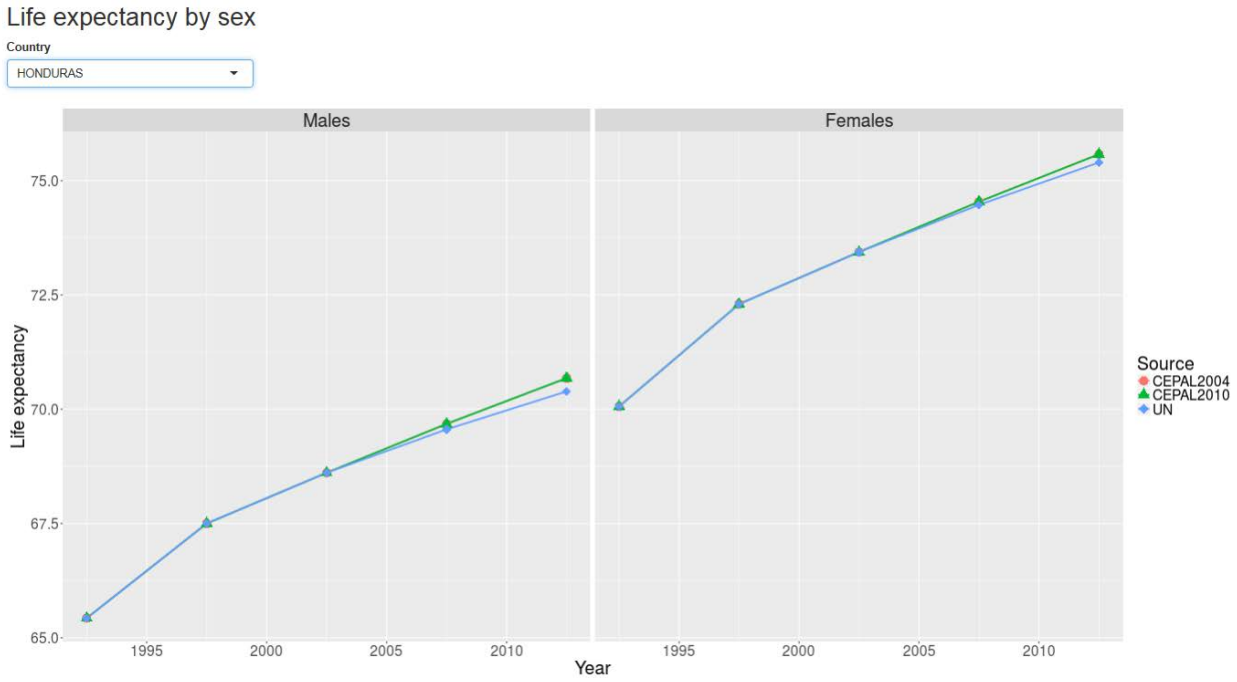

Figure 2b. Trends over time in the life expectancy at birth estimates, Mexico, 1990-2015

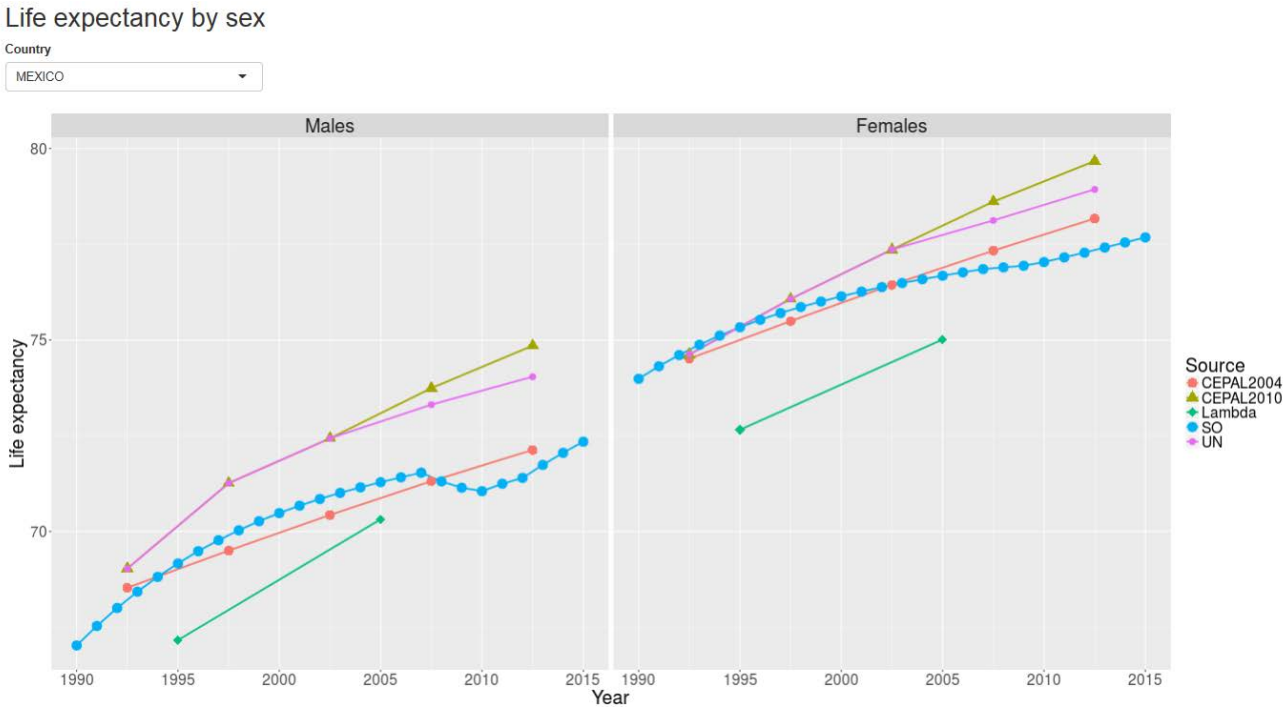

Figure 3a. Age- and cause-specific decomposition of the change in female life expectancy at birth for Peru, 1990-1994 to 1995-1999

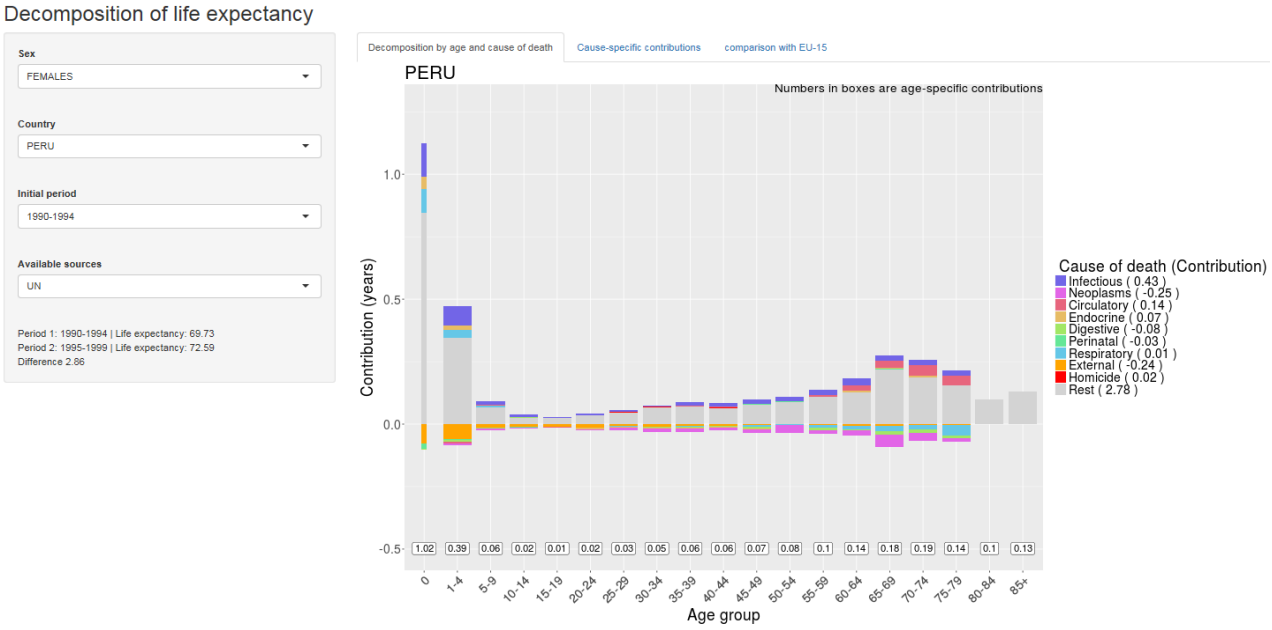

Figure 3b. Age- and cause-specific decomposition of the change in female life expectancy at birth for Panama, 2005-2009 to 2010-2014

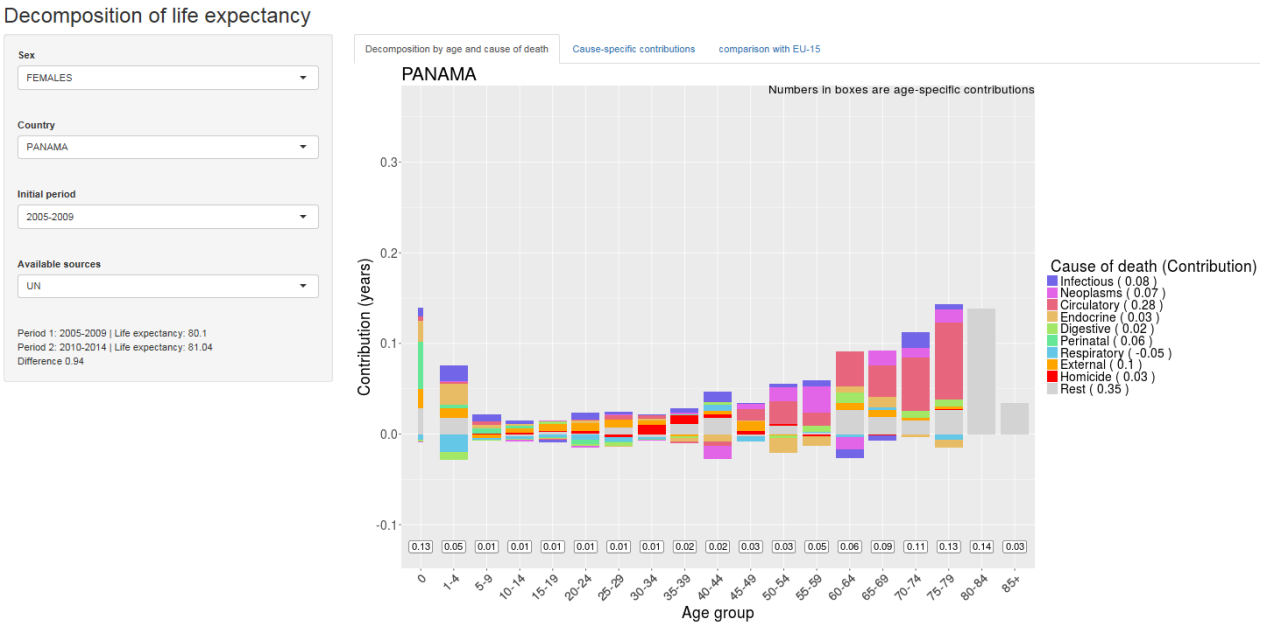

Figure 4a. Age- and cause-specific decomposition of the difference in male life expectancy at birth between EU-15 (life expectancy e_0= 80.24) and Venezuela (e_0=70.66) in 2010-2014

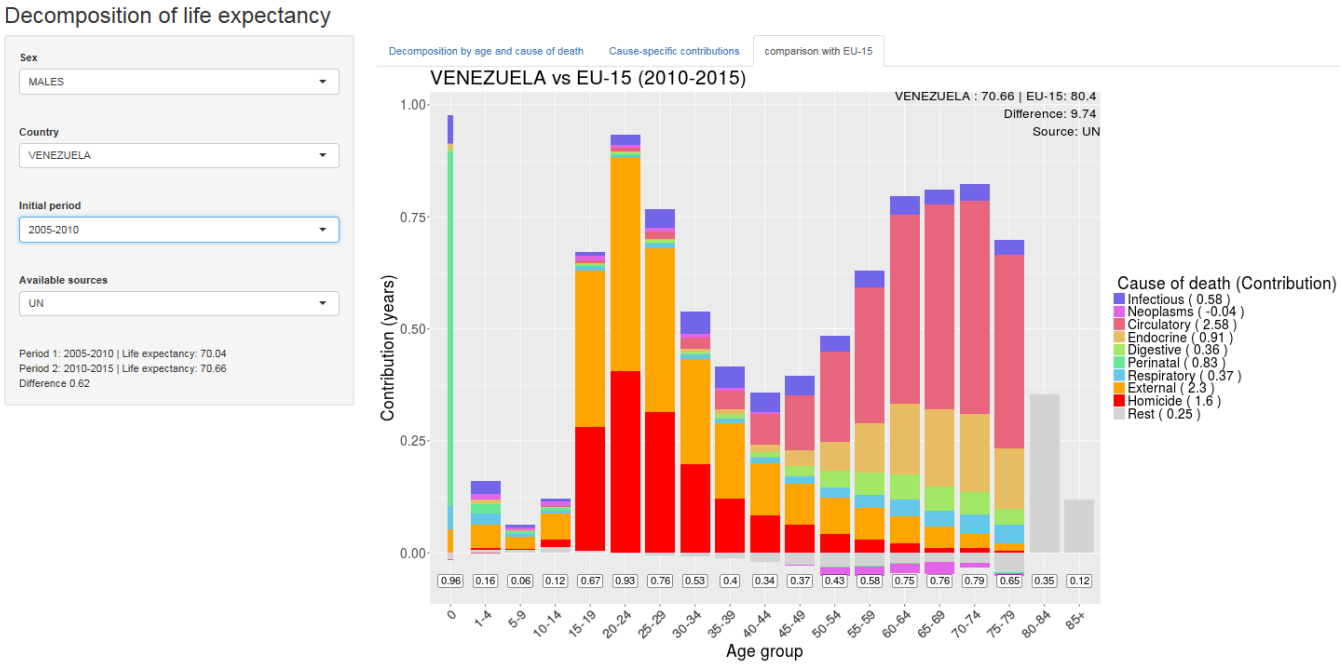

Figure 4b. Age- and cause-specific decomposition of the difference in female life expectancy at birth between EU-15 (life expectancy e_0= 85.17) and Venezuela (e_0=78.62) in 2010-2014