

# Supplemental Material: Declining Life Expectancy in the United States: Missing the Trees for the Forest

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## 1 DATA SOURCES AND METHODS

### 1.1 Data

We used a number of data sources to construct plots and to analyze life expectancy trends. Data on The underlying data source for our study was the US National Vital Statistics System, maintained by the National Center for Health Statistics (NCHS), which collects information on all deaths occurring in the United States each year. Although NCHS collects data on race and gender, accurate mortality statistics for Indigenous Americans are difficult to produce because of misclassification of Indigenous individuals as white on death certificates. Thirty percent of deaths to Indigenous individuals are estimated to be misclassified, hindering abilities to calculate life expectancy, attribute changes to specific causes of death, or calculate accurate, cause-specific mortality rates. In 2008, Arias and colleagues adjusted for misreporting of Indigenous ethnicity and estimated life expectancy for this group to be 71.1, 2.8 years lower than the next-lowest life expectancy estimate for Non-Hispanic Blacks. The age-adjusted mortality rate from opioid overdoses (not adjusted for ethnicity misreporting) was estimated to be between the mortality rates for non-Hispanic whites and non-Hispanic blacks during 2017-2018 (4). Even with under-reporting Indigenous Americans have the highest reported rates of suicide, and the second-highest reported rate of homicide in 2016 (5). While based on older data from 2009-2011, age-adjusted mortality rates that also adjusted for misreporting of Indigenous ethnicity were higher than the rates computed for all races for nearly all causes of death, with the highest rate ratios for alcohol-induced deaths, chronic liver disease and cirrhosis, diabetes, injuries, influenza/pneumonia, and drug poisoning (all with rate ratios  $\geq 1.8$ ) (6).

#### 1.1.1 CDC WONDER

We extracted mortality data by age, gender, and cause of death for various analyses using the CDC's Wide-ranging Online Data for Epidemiologic Research, called WONDER (Centers for Disease Control and Prevention and National Center for Health Statistics 2020)

### 1.1.2 SEER Stat

We calculated mortality rates by single-year-of-age and cause of death between 1983 and 2003 using software from the National Cancer Institute's Surveillance Research Program (National Cancer Institute 2019), for which the National Center for Health Statistics provides the underlying mortality data and population estimates.

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## 1.2 Estimation of life expectancy and decomposition

We used standard methods for creating abridged life tables (Preston, Heuveline, and Guillot 2001), with nineteen 5-year age groups (0-1, 1-4, 5-9, . . . , 85+) . We calculated the contribution of each age group and cause-of-death to the difference in life expectancy between the years 2014 and 2017 using the methods developed by Arriaga (Arriaga 1984). Briefly, the contribution of a particular age group is both a direct function of the difference in age-specific mortality rates at that age plus an additional contribution resulting from the fact that mortality differences at a given age will produce additional survivors at older ages (Arriaga 1984), given by the formula below:

$$n\Delta_x = \left[ \underbrace{l_x^{2017}/l_0^{2017}}_{\text{fraction of survivors}} \times \underbrace{\left( \frac{nL_x^{2014}}{l_x^{2014}} - \frac{nL_x^{2017}}{l_x^{2017}} \right)}_{\text{direct effect}} \right] + \left[ \underbrace{\frac{T_{x+n}^{2014}}{l_{x+n}^{2014}} \times \frac{\frac{l_x^{2017}l_{x+n}^{2014}}{l_x^{2014}} - l_{x+n}^{2017}}{l_0^{2017}}}_{\text{indirect effect + interaction}} \right]$$

where  $n\Delta_x$  is the total contribution for a given age interval between  $x$  and  $x + n$ ,  $l_x$  is number alive at age  $x$ ,  $L_x$  is the person-years lived in interval, and  $T_x$  is the person-time lived beyond age  $x$ .

The contribution  $n\Delta_x^i$  of each cause of death  $i$  within a given age group is a function of the difference between the two populations in the proportion of deaths due to a given cause (Arriaga 1989):

$$n\Delta_x^i = n\Delta_x \times \frac{\overbrace{\left( np_x^{i,2014} \times nr_x^{2014} \right) - \left( np_x^{i,2017} \times nr_x^{2017} \right)}^{\text{difference in share of deaths for cause } i}}{\underbrace{nr_x^{2014} - nr_x^{2017}}_{\text{overall mortality rate difference}}}$$

where  $n\Delta_x$  is the total contribution for an age group,  $np_x^i$  is the proportion of deaths within age group  $x$  due to cause  $i$ , and  $nr_x$  is the overall age-specific death rate. The total difference in life expectancy is the net sum of the age-cause components:

$$\sum_i n\Delta_x^i = n\Delta_x, \text{ and } e_0^{2014} - e_0^{2017} = \sum_x n\Delta_x = \sum_x \sum_i n\Delta_x^i$$

The total difference in life expectancy at birth between 2017 and 2014 is the sum of the age-cause specific components. The total contribution of a given age group to the difference in life expectancy is equal to the sum of its contributions across all causes of death. Likewise, the contribution of a particular cause of death is the sum of its contributions across age groups.

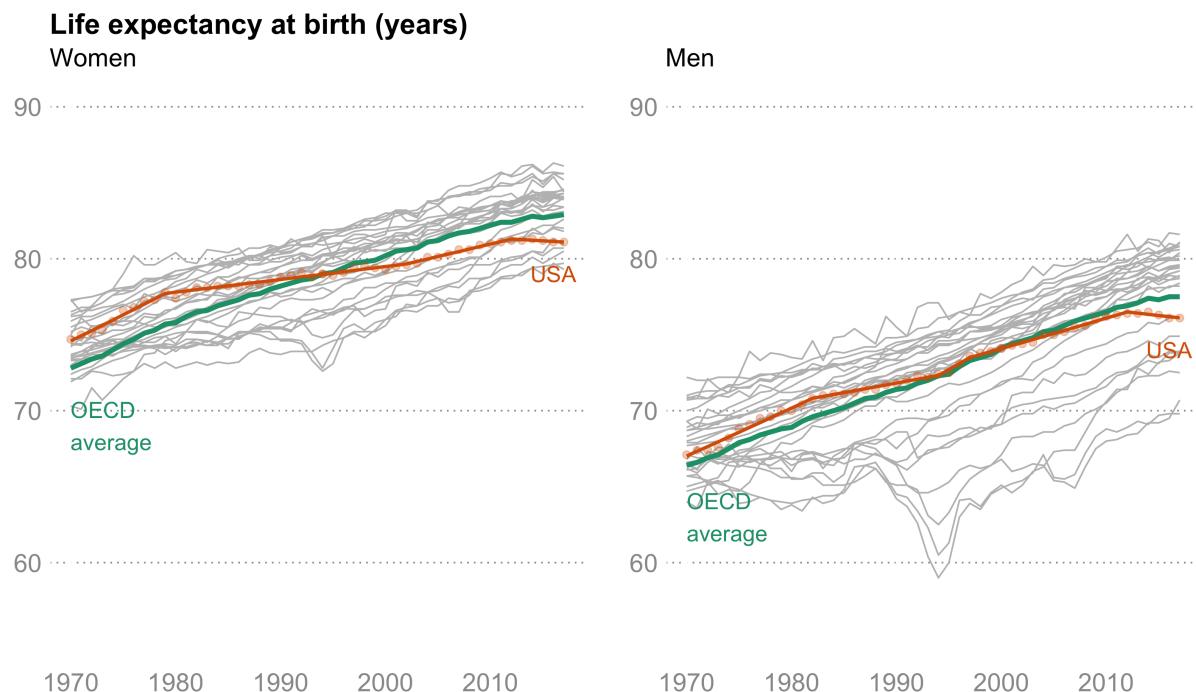
## 2 SUPPLEMENTAL TABLES AND FIGURES

The data and code to reproduce these tables and figures are provided here:

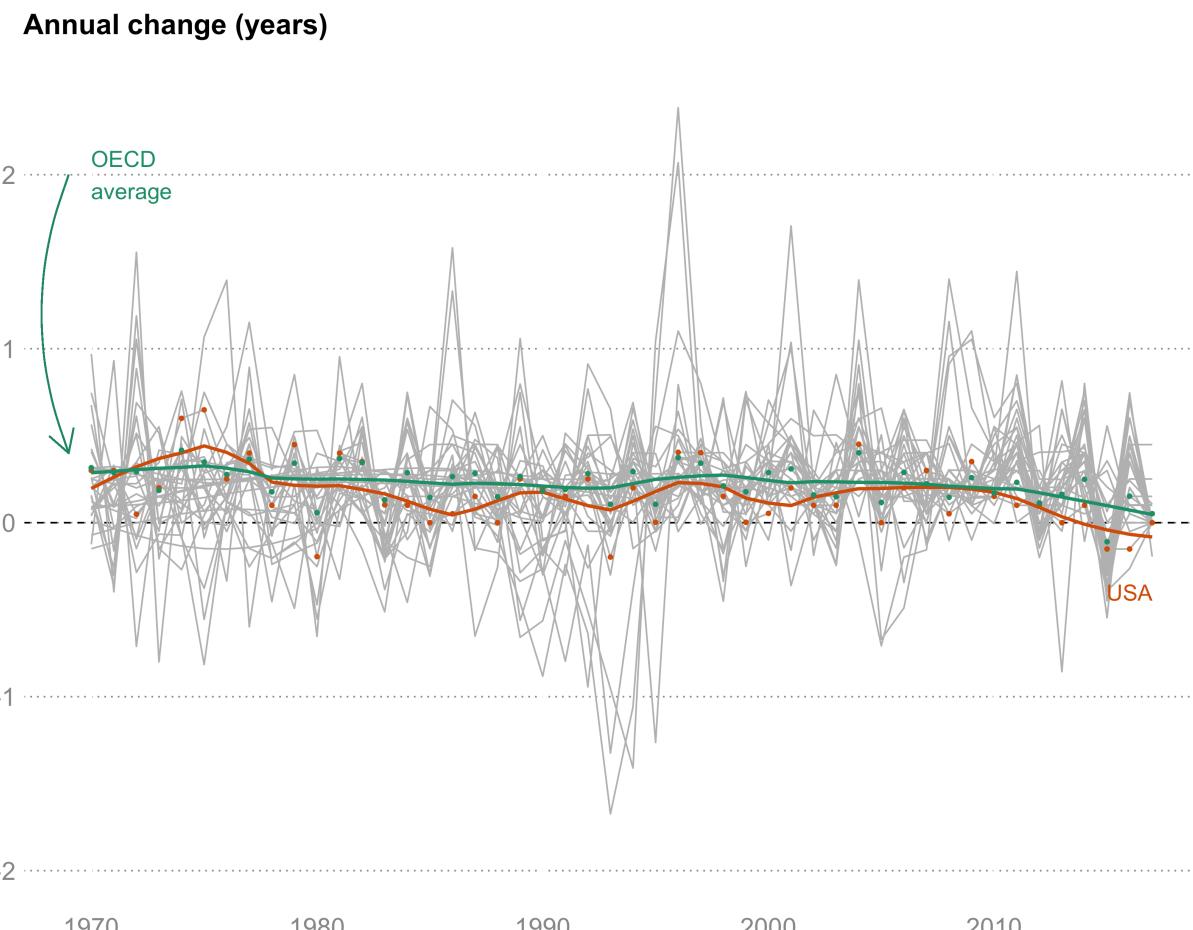
**Supplemental Table 1.** Life expectancy by gender and race-ethnicity, 1999-2018. Source: Authors' calculations of data from CDC WONDER (Centers for Disease Control and Prevention and National Center for Health Statistics 2020). Data: <https://osf.io/y4fzx/>, <https://osf.io/wsdvb/> Code: <https://osf.io/ewxm7/>

Year	Non-Hispanic API		Non-Hispanic Black		Non-Hispanic White		Hispanic	
	Women	Men	Women	Men	Women	Men	Women	Men
1999	86.6	81.3	74.9	67.8	79.8	74.7	83.0	77.2
2000	87.0	81.6	75.0	68.1	79.9	74.8	83.3	77.4
2001	87.1	82.0	75.3	68.4	79.9	74.9	83.3	77.6
2002	87.3	82.2	75.3	68.6	79.9	74.9	83.5	77.7
2003	87.4	82.5	75.5	68.8	80.0	75.1	83.6	77.9
2004	87.8	83.1	76.0	69.3	80.4	75.5	84.2	78.6
2005	87.9	82.9	76.1	69.4	80.4	75.5	84.1	78.2
2006	88.1	83.3	76.6	69.8	80.6	75.8	84.4	78.9
2007	88.5	83.8	77.0	70.2	80.9	76.0	84.9	79.3
2008	88.3	84.0	77.3	70.9	80.8	76.0	84.8	79.7
2009	88.7	84.2	77.8	71.4	81.2	76.4	85.4	80.1
2010	88.8	84.1	78.1	71.8	81.2	76.5	85.4	80.2
2011	89.2	84.7	78.3	72.2	81.2	76.5	85.8	80.8
2012	89.1	84.8	78.6	72.3	81.3	76.6	85.8	80.9
2013	89.5	84.7	78.6	72.4	81.3	76.6	86.0	81.0
2014	90.0	85.5	78.8	72.7	81.3	76.6	86.3	81.3
2015	89.7	85.4	78.8	72.4	81.1	76.5	86.3	81.2
2016	89.7	85.5	78.6	72.1	81.2	76.3	86.4	81.1
2017	89.7	85.3	78.8	72.0	81.1	76.3	86.4	81.1
2018	90.0	85.5	78.8	72.0	81.3	76.4	86.5	81.0
Changes								
2014-2017	-0.3	-0.2	0.0	-0.7	-0.2	-0.3	0.1	-0.2
2010-2018	1.2	1.4	0.7	0.2	0.1	-0.1	1.1	0.8

**Supplemental Figure 1.** Life expectancy at birth in the United States and 29 other high-income countries, 1969-2017. Source: World Development Indicators (The World Bank Group 2020). Data: <https://osf.io/d2b7c/>, <https://osf.io/n4mj6/> Code: <https://osf.io/muyrk/>

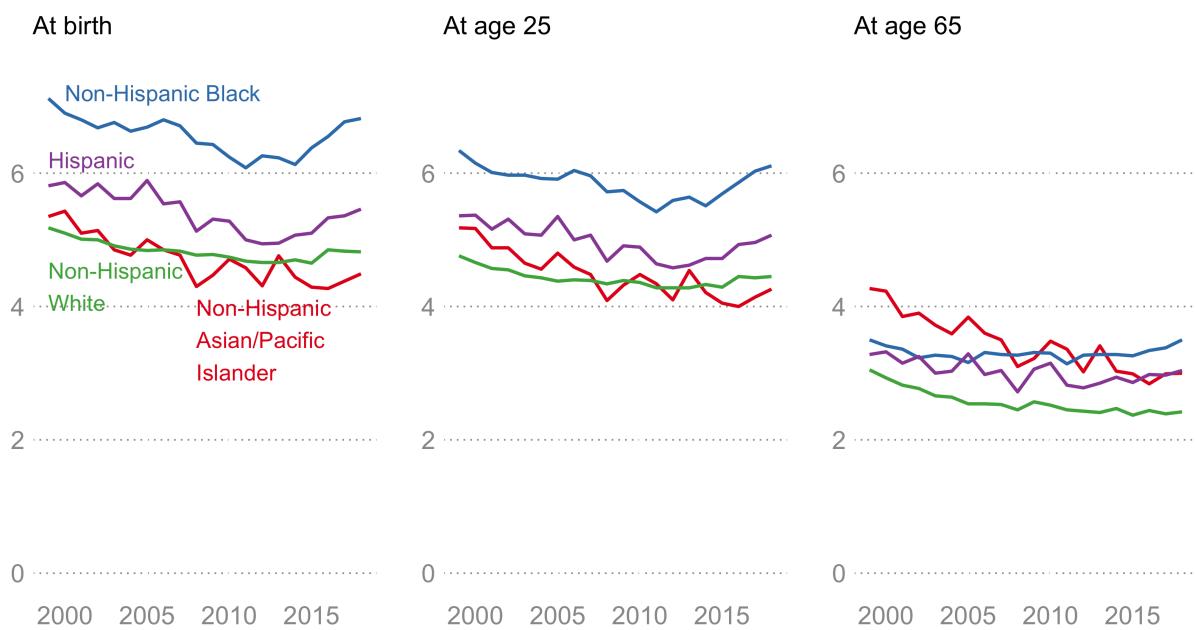


**Supplemental Figure 2.** Annual year-on-year change in life expectancy, USA and average of 29 other OECD countries. Source: World Development Indicators (6). Data: <https://osf.io/d2b7c/>, <https://osf.io/n4mj6/> Code: <https://osf.io/muyrk/>

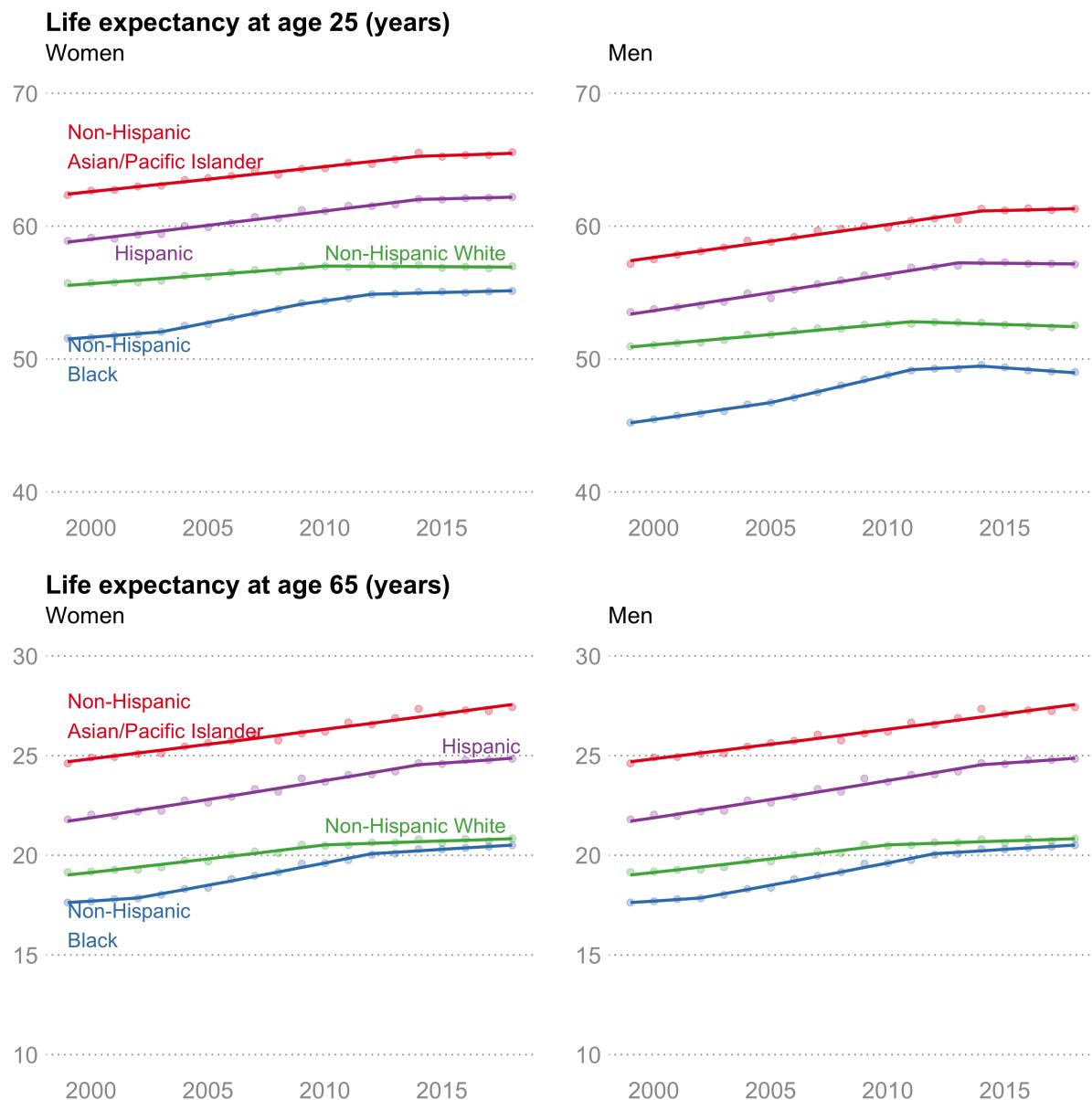


**Supplemental Figure 3.** Trends the gender gap in life expectancy by age and race-ethnicity, 1999-2018. Source: Authors' calculations of data from CDC WONDER (Centers for Disease Control and Prevention and National Center for Health Statistics 2020). Data: Code:

#### Gender gap (women - men) in life expectancy (years)



**Supplemental Figure 4.** Life expectancy at age 25 and age 65 in the United States, by gender and race-ethnicity, 1999-2018. Source: Authors' calculations of data from CDC WONDER (Centers for Disease Control and Prevention and National Center for Health Statistics 2020). Data: Code:



**Supplemental Figure 5.** Mortality rates by single years of age by race-ethnicity for women, ages 25-64. Source: Authors' calculations of data from CDC WONDER (Centers for Disease Control and Prevention and National Center for Health Statistics 2020). Data: Code:

Death rates per 100,000 by single years of age for women, 1999-2018

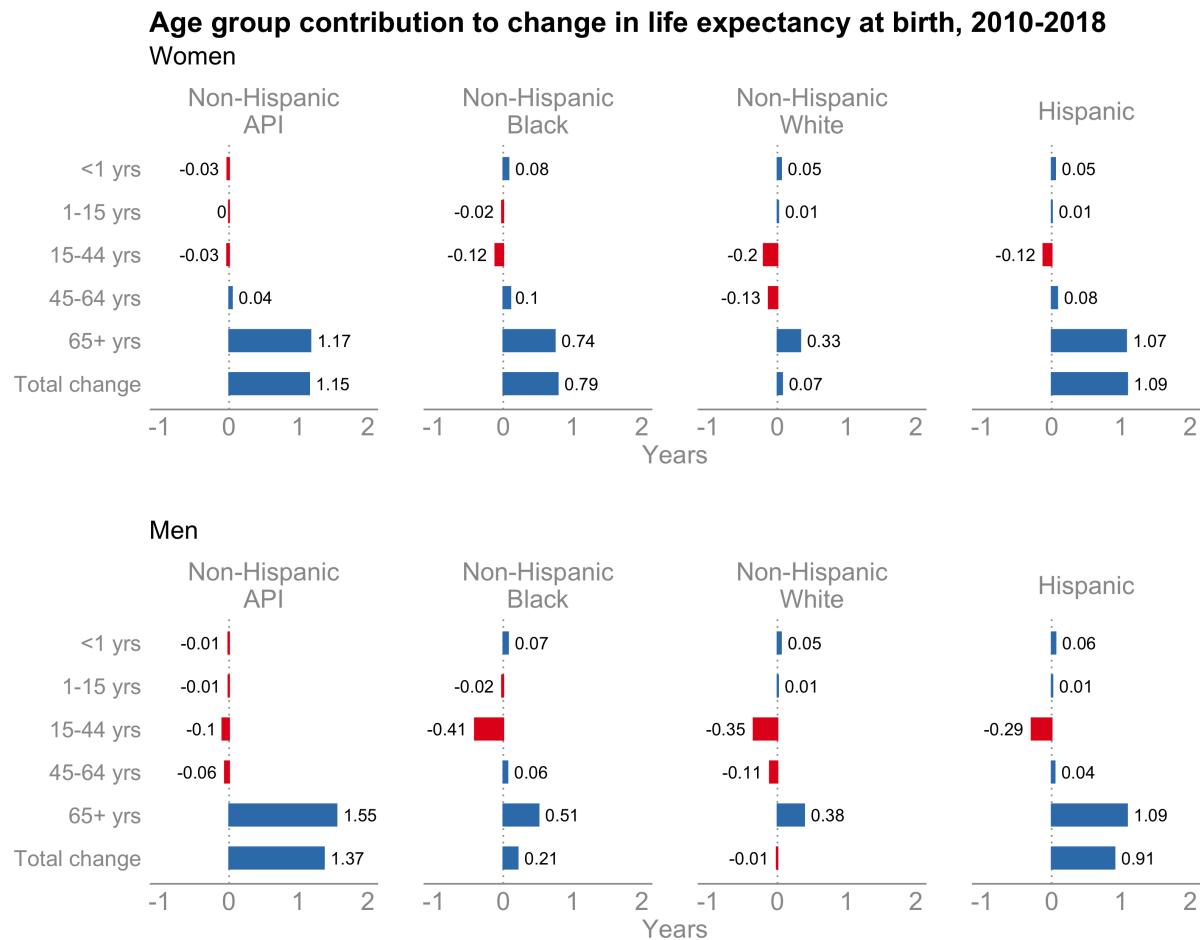


**Supplemental Figure 6.** Mortality rates by single years of age by race-ethnicity for men, ages 25-64. Source: Authors' calculations of data from CDC WONDER (Centers for Disease Control and Prevention and National Center for Health Statistics 2020). Data: Code:

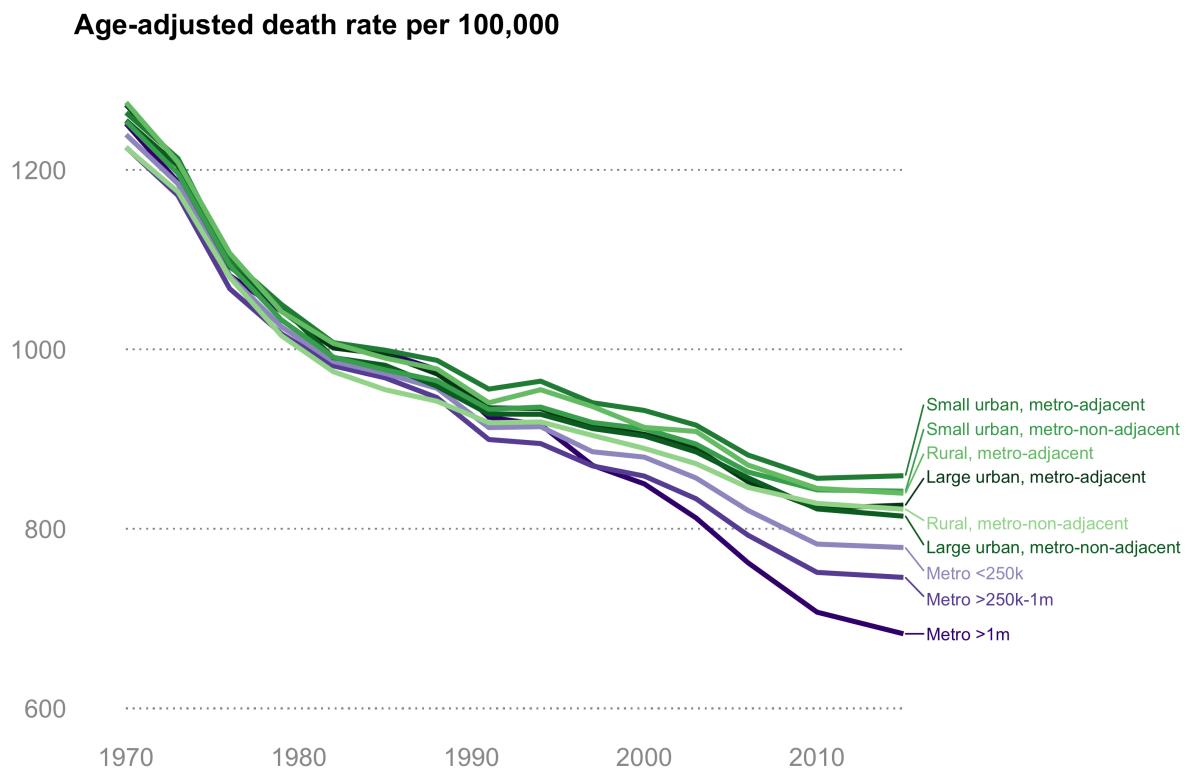
Death rates per 100,000 by single years of age for men, 1999-2018



**Supplemental Figure 7.** Age groups contributing to the change in life expectancy at birth in the United States between 2010 and 2018, by gender and race-ethnicity. Red color indicates age groups contributing a decline, blue color indicates age groups contributing an increase. Source: Authors' calculations of data from CDC WONDER (Centers for Disease Control and Prevention and National Center for Health Statistics 2020). Data: Code:

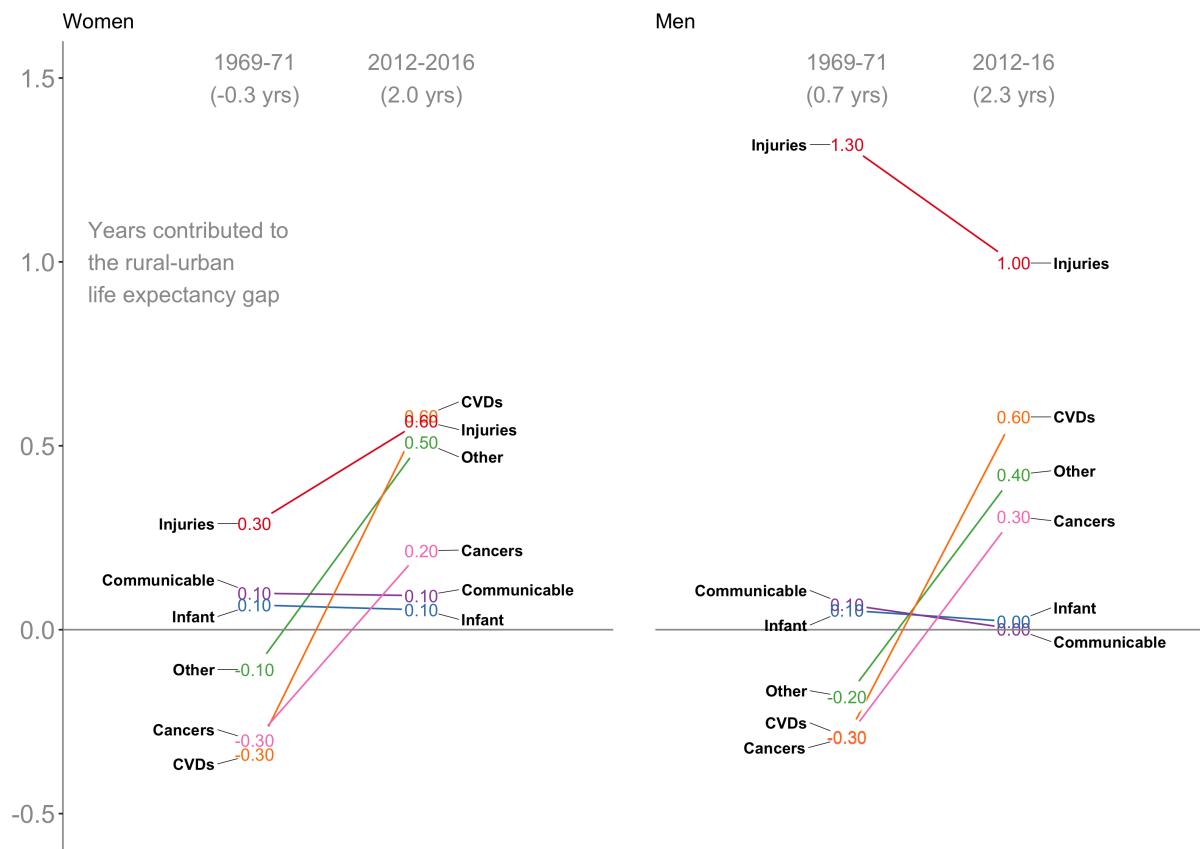


**Supplemental Figure 8.** Age-adjusted death rates per 100,000 by urban (purple) or rural (green) categorization, 1969-2016. Source: Authors' calculations of data from SEER\*Stat (National Cancer Institute 2019). Data: Code:



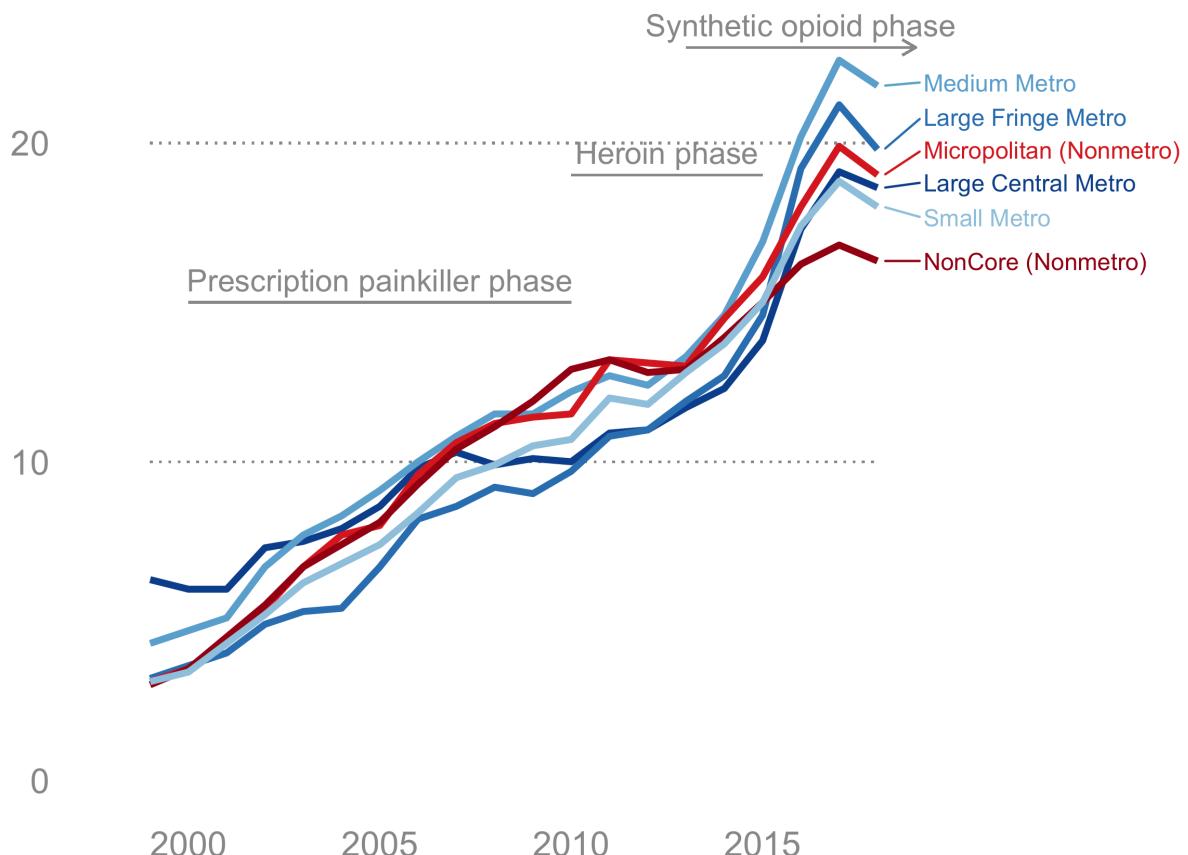
**Supplemental Figure 9.** Decomposition of the urban-rural life expectancy gap by cause-of-death, 1969-71 and 2012-16. Source: Authors' calculations of data from SEER\*Stat (3). Data: Code:

Major causes of death contributing to urban-rural differences in life expectancy at birth

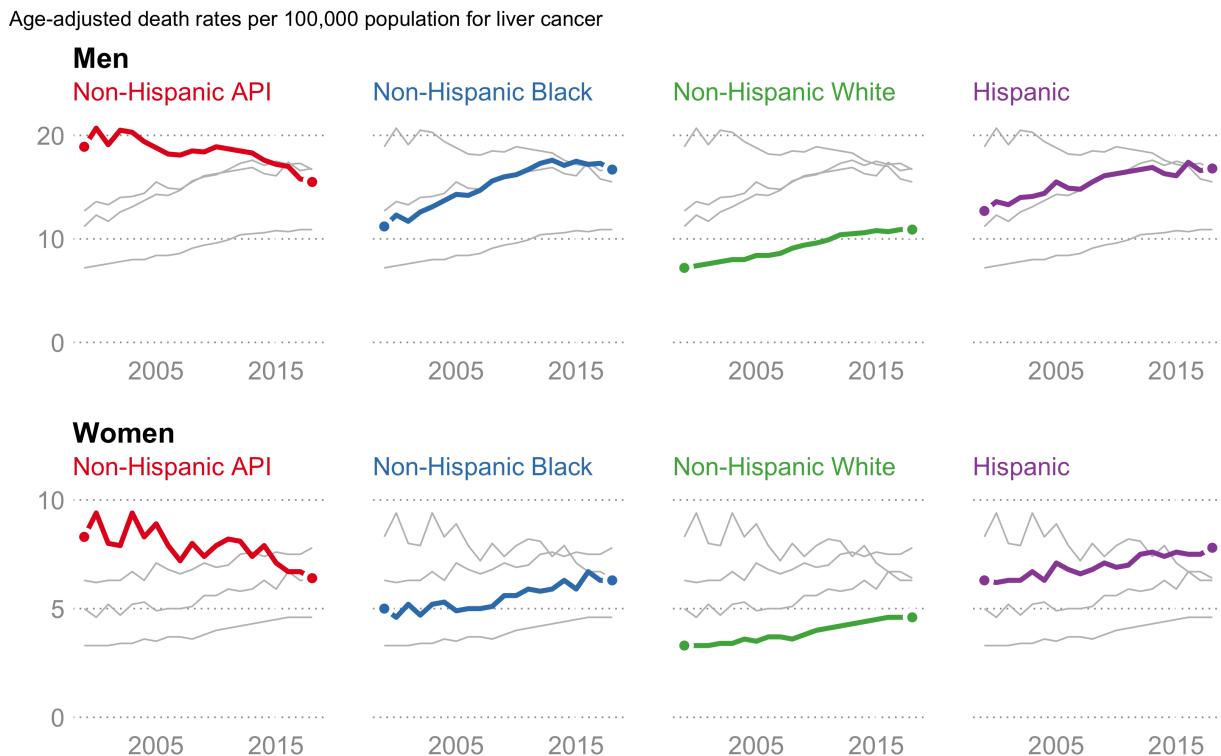


**Supplemental Figure 10.** Trends in age-adjusted unintentional poisoning death rates by urban-rural classification scheme, 1999-2018. Source: Authors' calculations of data from SEER\*Stat (3). Data: Code:

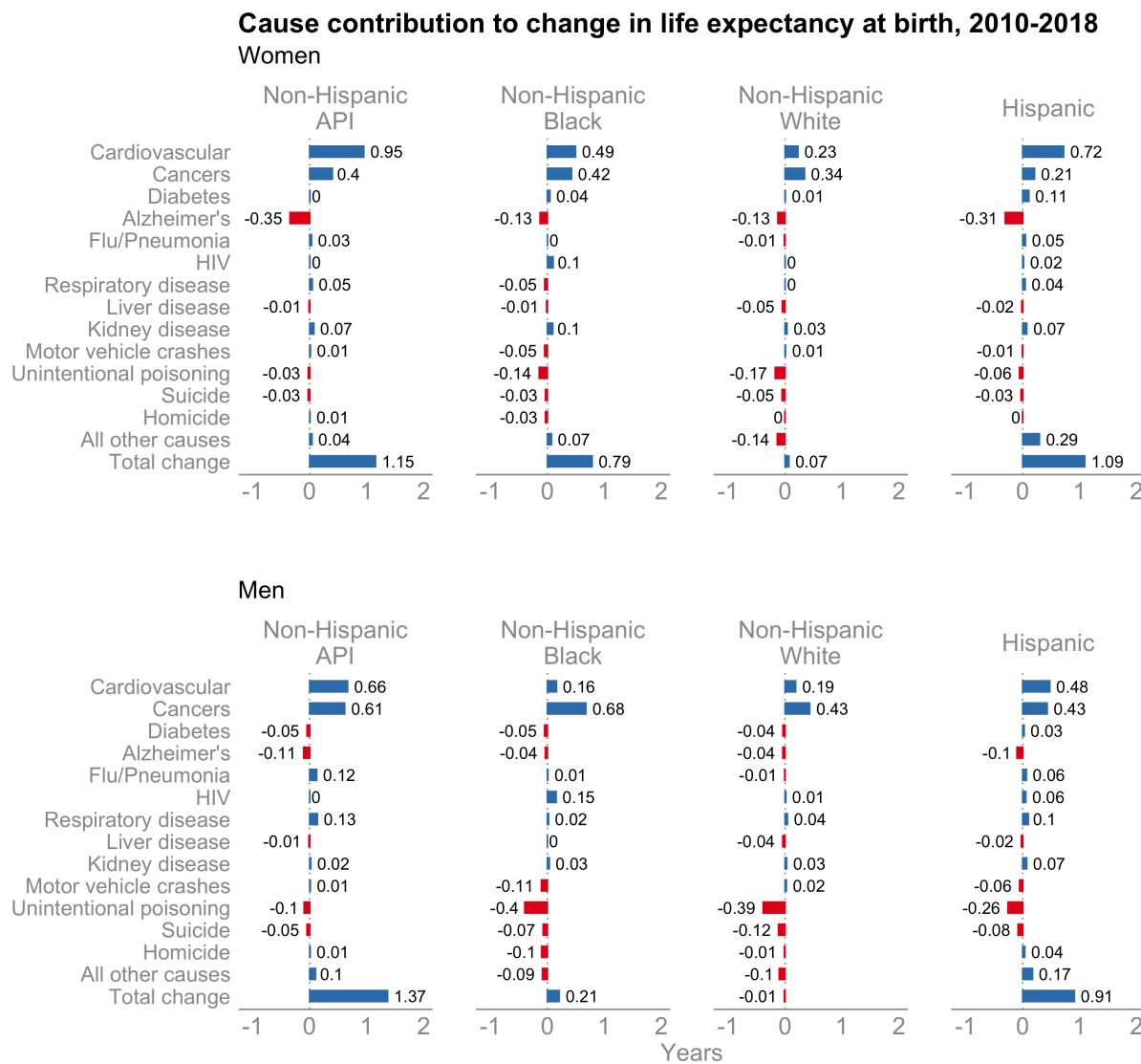
### Age-adjusted unintentional poisoning death rate per 100,000



**Supplemental Figure 11.** Trends in age-adjusted liver cancer death rates by race-ethnicity and gender, 1999-2018. Source: Authors' calculations of data from CDC WONDER (1). Data: Code:



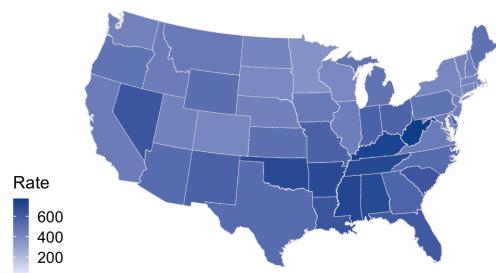
**Supplemental Figure 12.** Causes of death contributing to the change in life expectancy at birth in the United States between 2010 and 2018, by gender and race-ethnicity. Red color indicates causes contributing a decline, blue color indicates causes contributing an increase. Source: Authors' calculations of data from CDC WONDER (Centers for Disease Control and Prevention and National Center for Health Statistics 2020). Data: Code:



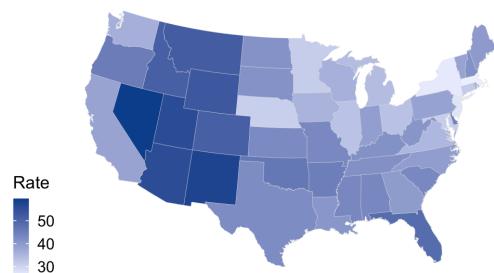
**Supplemental Figure 13.** Age-adjusted death rates per 100,000 for non-Hispanic white men aged 45-54, by state, 2010-2018. Source: Authors' calculations of data from CDC WONDER (Centers for Disease Control and Prevention and National Center for Health Statistics 2020). Data: Code:

Age-adjusted death rates per 100,000 for non-Hispanic white men aged 45-54, 2010-2018

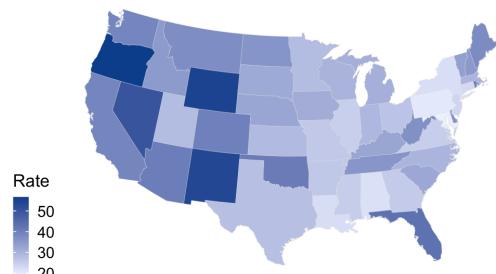
All causes



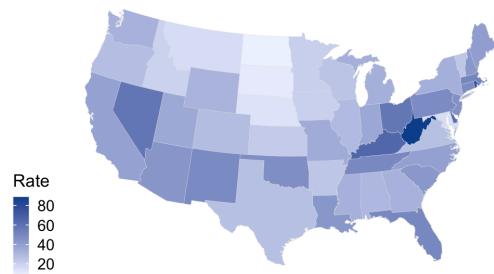
Suicides



Alcohol-related



Unintentional poisoning



## LITERATURE CITED

- Arriaga, Eduardo E. 1989. "Changing Trends in Mortality Decline During the Last Decades." In *Differential Mortality: Methodological Issues and Biosocial Factors*, edited by LT Ruzicka, GJ Wunsch, and P Kane, 105–29. Oxford, England: Clarendon Press.
- . 1984. "Measuring and Explaining the Change in Life Expectancies." *Demography* 21 (1): 83–96. <https://doi.org/10.2307/2061029>.
- Centers for Disease Control and Prevention, and National Center for Health Statistics. 2020. "Underlying Cause of Death, 1999-2018 on CDC WONDER Online Database, Released in 2020. Data Are from the Multiple Cause of Death Files, 1999-2018." <https://wonder.cdc.gov/ucd-icd10.html>.
- National Cancer Institute. 2019. "SEER\*Stat Version 8.3.6. SEER\*Stat Database: Mortality - All COD, Aggregated with County, Total U.S. (1969-2017) - Linked to County Attributes - Total U.S., 1969-2018 Counties." Hyattsville, Maryland: National Cancer Institute, Surveillance Research Program.
- Preston, Samuel H., Patrick Heuveline, and Michel Guillot. 2001. *Demography: Measuring and Modeling Population Processes*. Malden, Mass.: Blackwell.
- The World Bank Group. 2020. "World Development Indicators | DataBank." <https://databank.worldbank.org/source/development-indicators>.