# The Health Transition Derailed:
An analysis of inter-state variations in adult mortality patterns in the United States since 1959

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EXTENDED ABSTRACT

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**Abstract**

In this paper, we use series of death counts by sex, age and underlying cause available through the National Center for Health Statistics for each state of the United States (and the District of Columbia) for years 1959-2011 to document discontinuities in adult mortality trends and their geographic variations. We particularly investigate differences by state in achieving three major epidemiologic transitions corresponding to the successive control of infectious diseases, cardiovascular diseases, and cancer. By identifying the age groups and causes of death that have most contributed to discontinuities in trends across U.S. states, we question whether the failure to progress along a single transition path explains current geographic inequalities in mortality. We also assess how much of the inability of various states to latch on these three major epidemiologic transitions is responsible for the continuous deterioration of the U.S. position in international ranking on life expectancy at birth.

## Introduction

Inter-state variations in expectation of life at birth remain large in the United States. As indicated by prior research, geographic inequalities in mortality have even increased since around 1980 and they play an important role in explaining the progressive deterioration of the United States position in international ranking on health (Ezzati et al., 2008; Kindig and Cheng, 2013; Wilmoth, Boe, and Barbieri, 2009; Wang et al., 2013). Assuming a unique pattern of epidemiologic change, this paper investigates to which extent current variations in inter-state mortality can be explained by the inability of some states to successfully progress on the typical health transition path.

Four major stages in the health transition have been described in the classic model, each corresponding to the control of a major group of diseases, namely infectious diseases, cardiovascular diseases, cancer, and senescence. Though Omran developed the initial concept of the health transition, a number of revisions have been made to the theory as the geographic scope of investigations has increased and as recent epidemiologic changes in low-mortality countries have continued to unfold (Frenk, 1991; Horiuchi, 1999; Olshanksky et al., 1998; Omran, 1970). A review of the literature on the health transition status around the world indicates that areas which are lagging behind in terms of their level of life expectancy at birth are those which failed to progress through one of these four epidemiologic stages. For instance, most countries in Sub-Saharan Africa are still struggling to control some major infectious diseases and in former countries of the Soviet Union, mortality from cardiovascular diseases remains much higher than in all other high-income countries (Vallin and Meslé, 2004).

In this paper, we focus on the first three transitions listed above and we investigate whether a similar pattern of failed transitions can explain geographic variations in life expectancy at birth across the U.S. Using mortality statistics by state, sex, age and cause available through the National Center for Health Statistics for years 1959-2011 and corresponding population estimates, we seek to identify discontinuities along the health transition path, which might explain current inter-state variations in life expectancy at birth.

## Data

The National Center for Health Statistics (NCHS) produces public-access electronic files of exhaustive death counts in the U.S. by year of occurrence, sex, age and the underlying cause of death for each calendar year since 1959. Information on the state of residence is only available for years up to 2004 included, due to increasing concerns over privacy issues.[1] In January 2013, the National Cancer Institute released annual time series of July 1st U.S. county population estimates by age and sex for single calendar years from 1969 up until 2011 thru its Surveillance, Epidemiology and End Result (SEER) program. Taken together, these data on death and population counts can be used to compute all-cause and cause-specific mortality rates by age group for each state, year, and sex for years 1969 through 2004. In order to extend these all-cause and cause-specific mortality rates back to 1959, we are currently in the process of

[1] For the period 2005-2011, however, we were granted permission to access the data through the NCHS Data Center and to obtain the information on the state of residency of all deceased individuals. Therefore, we intend to extend our data series by seven calendar years in the next version of this paper.

reconstructing annual time series of July 1st population estimates by age and sex for each U.S. state for the period 1959-1968. These population estimates are being computed based on population counts from the 1960 and 1970 U.S. censuses and vital statistics data, using an adapted-version of the Human Mortality Database methodology (Wilmoth et al., 2007, p.16-27).

To facilitate interpretation, detailed causes of death were combined into a set of 11 categories. These categories were determined based on the similarity of their risk factors and on their nosological consistency over time. Indeed, the original cause-of-death data were coded into the International Classification of Disease scheme, which has been revised four times over the period under consideration here (from ICD-7 to ICD-10). They can be further grouped into three broad categories, namely: 1) diseases of the circulatory system (Cerebrovascular diseases; Heart diseases; All other diseases of the circulatory system), 2) cancer (Lung cancer; Other smoking-related cancers; Prostate cancer; Breast cancer; Uterus cancer; Stomach cancer; All other malignant neoplasms), and 3) All other diseases. The smoking-related cancer category includes most cancers of the respiratory and digestive tracts, namely cancers of the lip, oral cavity, pharynx, esophagus, larynx, trachea, bronchus, and lung. The predominant role of cigarette smoking in the incidence of these cancers is well documented (Doll et al. 2004; Rogers et al. 2005; Thun et al. 1997; U.S. Department of Health and Human Services 2004). Smoking also has some impact on the other types of cancers but a host of additional factors are known to increase their risks independently from smoking. The concordance table used for bridging the four revisions of the ICD is presented in the Appendix, with specific codes for each category in each time period (Appendix Table 1).

## Methods

The idea behind the methods implemented in this study is to identify the major turning points in mortality trends and to compare them across all states and, within each state, across age groups and disease categories. The goal is to uncover different patterns of epidemiologic change in relation to current mortality status.

As a first step, we will study all-cause mortality data to identify any sudden onset of mortality decline over the period of interest for the various states. We will compute age-standardized death rates by single calendar year, sex, and state using the total (both sexes) population of the United States by five-year age groups in 1980 (corresponding roughly to the middle point of the study period) as the standard. To assess the timing and magnitude of the turning point in mortality trends, we will fit trend lines to these age-standardized death rates over time. Experimenting with a range of statistical approaches in previous work, we found that a grid-search type algorithm based on $R^2$ goodness-of-fit criteria provided a fit as good as that with more sophisticated methods but in a more simple and less arbitrary way (Ouellette, Barbieri, and Wilmoth, 2012).

More specifically, we will estimate two- or (where relevant) three-slope regression models for each state and interpret the turning point(s) for the slope as an indicator of the timing of the dominant discontinuity(ies) in the mortality trends. Turning point(s) will be allowed to occur in any calendar year throughout the entire period studied. We will select the one(s) providing the best description of the data, that is, the one(s) maximizing the goodness-of-fit in $R^2$. For example, Figure 1 shows that based on data for U.S. males over the 1959-2004 period, the dominant turning point for the slope in all-cause age-standardized death rate (ASDR) occurred in 1966, yielding the following regression model:

$$ASDR = \beta_0 + \beta_1 ( year - 1950 ) + \beta_2 ( year - 1966 ) I_{year>1966} + \varepsilon,$$

where $I_{year>1966}$ is an indicator variable that equals one after 1966 and zero otherwise. Of the three model parameters in this equation, $\beta_2$ is the most important one for our purpose, as it corresponds to the change in the slope of the mortality trend before and after the turning point. Therefore, a higher estimate for $\beta_2$ (in absolute value) suggests a sharper mortality change and vice-versa and the parameter can be used to assess the magnitude of the discontinuity in trend.

[FIGURE 1 about here]

In a second step, we will conduct an analysis of cause-specific mortality data to identify the categories of diseases that contributed most to the all-cause mortality change observed across all states. In order to attenuate fluctuations, the death rates will be smoothed over five-year windows centered on each successive calendar year in the series (excluding the first and last two years available). The multiple-slope regression model described above will also be used to look for the dominant turning point(s) in U.S. states' age-standardized death rate trends over time by sex for each cause-of-death category.

**Preliminary Results**

Figures 2 and 3 present all-cause age-standardized death rate series for men and women aged 40 years and above for the period 1969-2004[2] for all U.S. states grouped into their respective geographic regions. The first main finding is that even in 1969, states exhibited a wide range of mortality levels, especially for males, with death rates ranging from 27 per 1,000 in Hawaii to 42 per 1,000 in the District of Columbia. Considering that most of the progress achieved during the first half of the 20th century centered on the main infectious diseases, extending the series back to 1959 will be crucial in determining how successful the various states have been at controlling such diseases by the time the next large epidemiologic transition (i.e., the so-called cardiovascular revolution) potentially fostered further inter-state divergences in mortality.

A second main finding is that of a striking similarity in both levels and trends for most states within their respective geographical regions. The mortality curves are not only parallel to one another in each graph but they overlap heavily. The main exceptions to this pattern are, for males only: Connecticut (compared to the other states in New England) and Pennsylvania (Middle Atlantic); and for both sexes: Wisconsin (East North Central), Missouri (West North Central), Nevada (Mountain), Hawaii (Pacific), District of Columbia and Florida (South Atlantic) and Louisiana (West South Central). For all of these states, the mortality curves are either clearly below or clearly above those of their neighboring states.

[2] As mentioned above, the age-standardized mortality series by state will be constructed for the whole 1959-2011 period in the actual paper, after 1) annual population estimates will have been produced for years 1959-1968 using the Human Mortality Database methods protocol (Wilmoth et al., 2007, p.16-27), and 2) detailed mortality files that have just been received from the NCHS Data Center for years 2005-2011 will have been processed.

Third, the overall pattern is substantially different for men and women. For **men**, all states show a very rapid and continuous mortality decline throughout the period. In nearly every one of them, the age-standardized death rate was halved between 1969 and 2004. States in the East South Central region (Alabama, Kentucky, Mississippi, and Tennessee) represent the main exception to this pattern to the extent that their decline in mortality rates at ages 40 years and above started to slow down around 1980. A few additional states depart from their regional patterns in that they experienced a period of stalling mortality. Most typical in this respect are Nevada (in the Mountain region), the District of Columbia (South Atlantic) and, to a smaller extent, Hawaii (Pacific), and Oklahoma and Arizona (West South Central). For **women**, there are two clearly demarcated mortality episodes. Trends in the age-standardized death rates for ages 40 and above are fairly similar to those for men up to around 1980. Then, progress appears to have stopped or to have slowed down significantly. In some states (those located in the East South Central region as well as Georgia, Kansas, Oklahoma, West Virginia and Wyoming), mortality even appears to have increased during the last two decades of the 20$^{th}$ century.

[FIGURES 2 and 3 about here]

We anticipate that extending the death rate series back to 1959 and forward to 2011 will uncover further points of discontinuity and help us to better define each of these main findings. Moreover, analysis of cause-specific mortality trends will further increase our understanding of the factors driving these changes in trends as well as the reasons for the geographic variations in levels and trends across all U.S. states. Our results will feed into a discussion of the respective roles of changes in behaviors (and in the policies inducing behavioral changes) and changes in health care (in terms of both medical progress and access to services) as drivers of mortality patterns and differentials.

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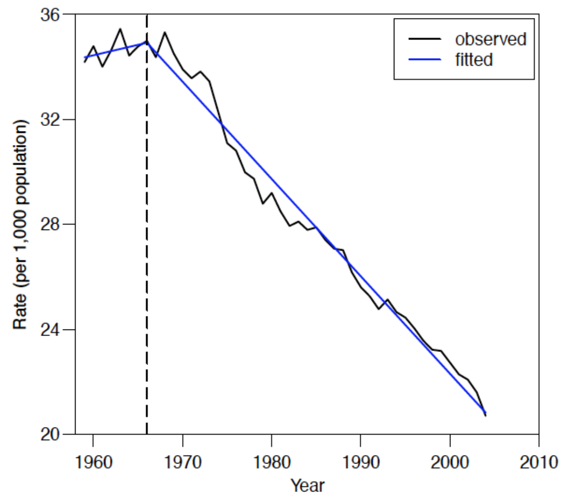
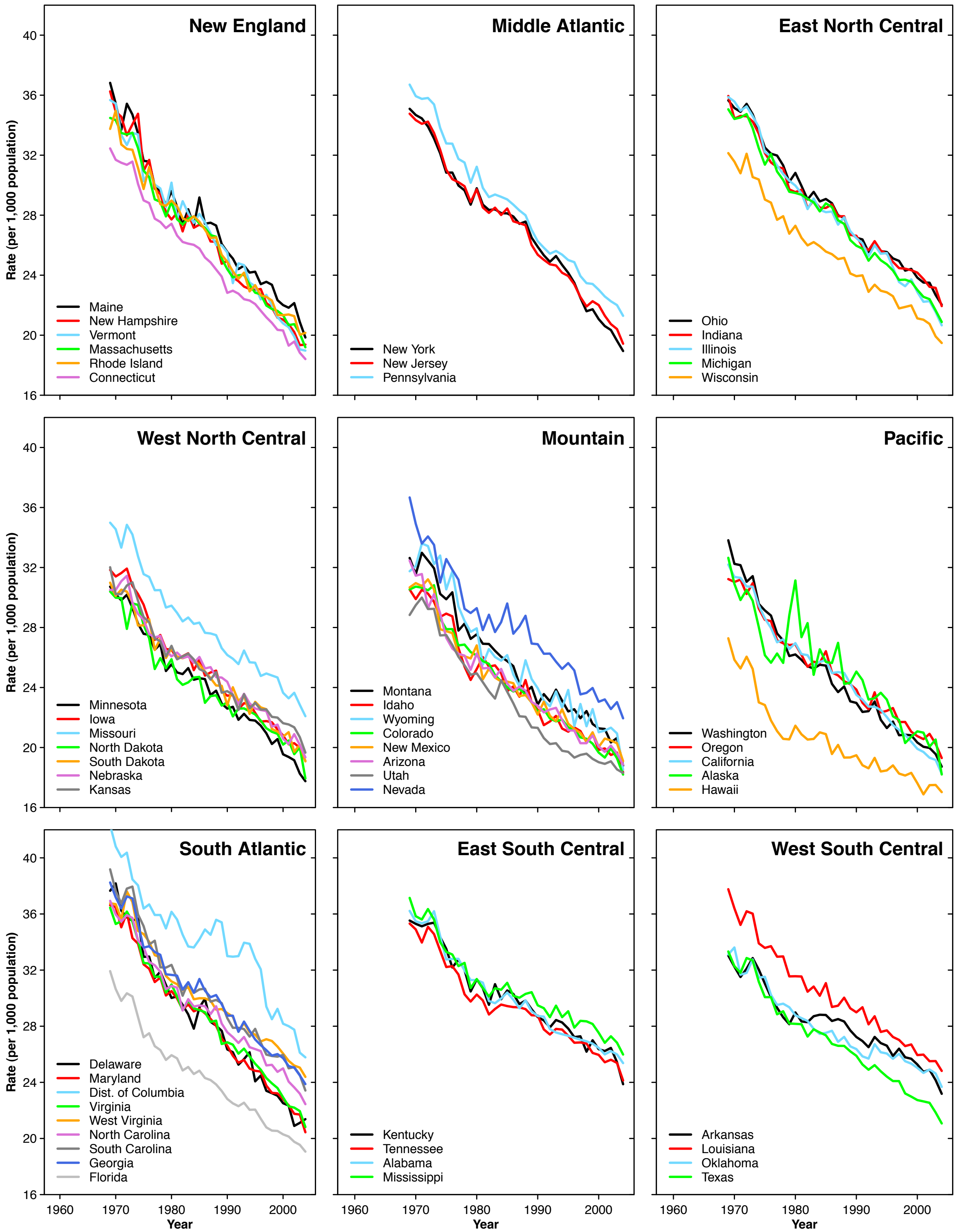
**Figure 1**: Age-standardized death rates in the United States with trend lines, males, ages 40 and above, 1959-2004



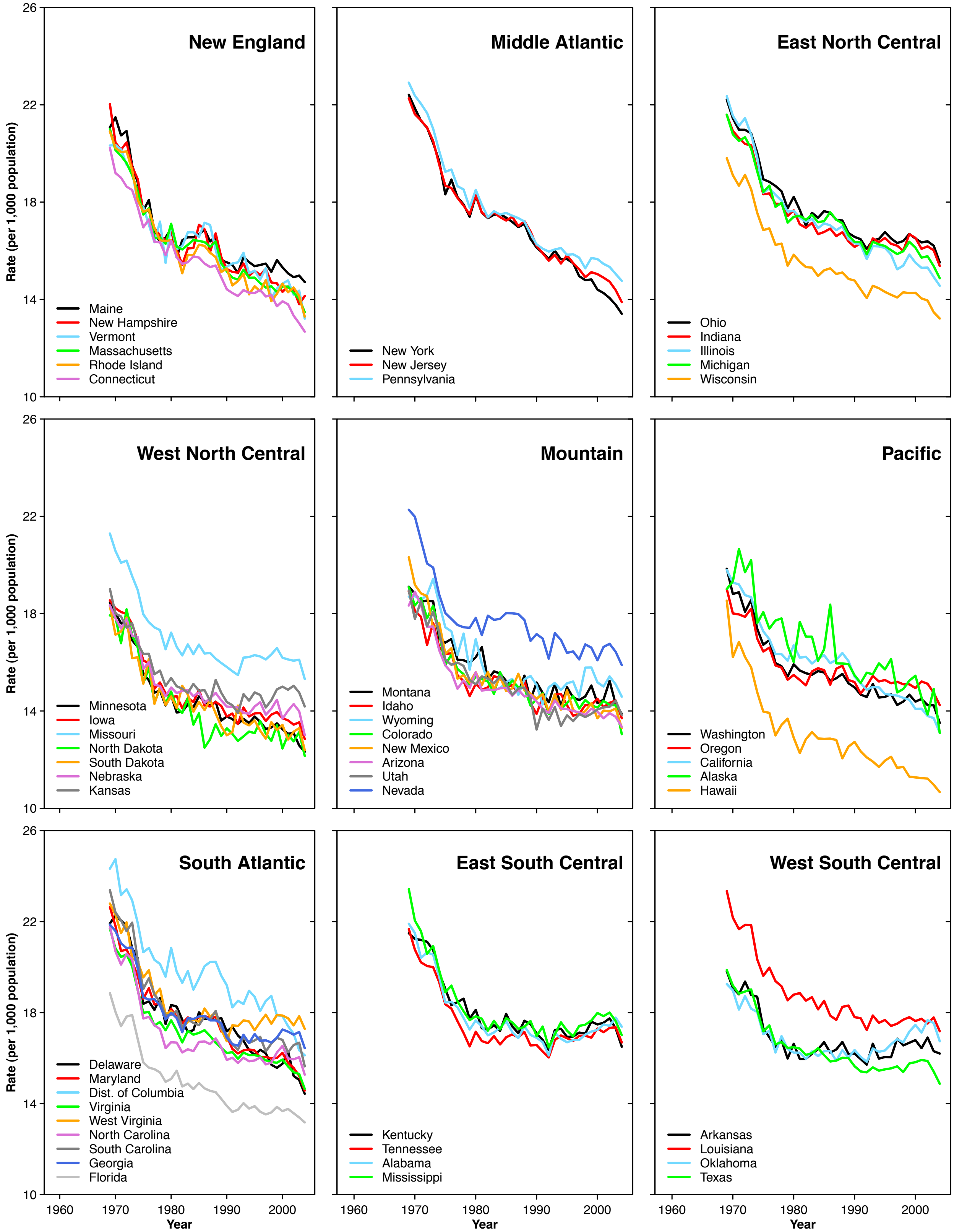

Notes: The standard population corresponds to the total (both sexes) U.S. population in 1970. The vertical dashed line indicates the year of the dominant turning point in trend, according to the best fitting two-slope regression model (by a criterion of maximum $R^2$).

**Figure 2**: Age-standardized death rates in U.S. states, ages 40 and above, 1969-2004, males




*Note*: The standard population corresponds to the total (both sexes) U.S. population in 1980.

**Figure 3**: Age-standardized death rates in U.S. states, ages 40 and above, 1969-2004, females




*Note*: The standard population corresponds to the total (both sexes) U.S. population in 1980.

**Appendix Table 1**: Cause-of-death categories and their ICD codes, ICD-7 through ICD-10

| **Cause-of-death category** | **ICD Revision and ICD codes** | | | |
|---|---|---|---|---|
| | **ICD-7** | **ICD-8** | **ICD-9** | **ICD-10** |
| **Diseases of the circulatory system** | **330-334, 400-468** | **390-458** | **390-459** | **I00-I99** |
| Cerebrovascular diseases | 330-334 | 430-438 | 430-438 | I60-I69 |
| Heart diseases | 400-456 | 390-429, 440-458 | 390-429 | I00-I52 |
| All other diseases of the circulatory system | 460-464, 465-468 | 450-458 | 440-459 | I70-I99 |
| **Cancer (malignant neoplasms)** | **140-205** | **140-209** | **140-208** | **C00-C97** |
| Lung cancer | 162-163 | 162 | 162 | C33-C34 |
| Other-smoking related cancers | 140-148, 150, 161-163 | 140-149, 150, 161-162 | 140-150, 161-162 | C00-C15, C32-C34 |
| Prostate cancer | 177 | 185 | 185 | C61 |
| Breast cancer | 170 | 174 | 174, 175 | C50 |
| Uterus cancer | 171-174 | 180-182 | 179-182 | C53-C55 |
| Stomach cancer | 151 | 151 | 151 | C16 |
| All other malignant neoplasms | 152-160, 164-169, 175-176, 178-205 | 152-160, 163-173, 175-179, 183-184, 186-209 | 152-160, 163-173, 176-177, 183-184, 186-208 | C17-C31, C35-C49, C51-C52, C56-C60, C62-C97 |
| **All other conditions** | **001-138, 210-326, 340-398, 470-795, E800-E999** | **000-136, 210-389, 460-796, E800-E999** | **001-139, 209-389, 460-799, E800-E999** | **A00-B99, D00-H95, J00- R99, S00-Z99, U00-U99** |

*Source:* Assembled by the authors from various sources.