Visualizing Mortality Dynamics for Causes of Death

Extended Abstract

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November 15, 2013

Abstract

Life expectancy increased in countries like Sweden, France or Italy at a steady pace during the past half century. The development in some other countries (e.g., Denmark, the US or East Germany) can be characterized by periods of stagnation and subsequent years of catching up to other countries. The underlying dynamics for the comparable trends in life expectancy in the latter group can be quite diverse, though. We present Lexis maps of rates of mortality improvement, which depict the time-derivative of age-specific death rates, to illustrate those dynamics. We suggest that the resulting maps are easily understandable and interpretable. By analyzing selected causes of death in the United States, we argue that the identification of major developments, such as period- and cohort effects, is straightforward. Although circulatory diseases are the largest cause-of-death category, they were not the reason for the slow development of life expectancy among women in the US. Our visual analysis suggests that behavioral factors are mainly to blame: The main driver for the slow increase in life expectancy during the 1980s and 1990s was death from malignant neoplasms. The maps show a cohort pattern for all cancers combined, primarily shaped by lung cancer mortality. With increasing death rates at virtually all ages (=period effect), diabetes contributed also to this problematic trend in the US during the last two decades of the twentieth century but the pattern has reversed in recent years. Our goal in subsequent steps is to conduct a comparative analysis across several countries to gain a broader and deeper understanding of the underlying mortality dynamics. A preliminary figure for all-cause mortality shows, for instance, that Hungary's mortality dynamics differed considerably from the ones observed in the US and Denmark — despite comparable trends for life expectancy in general.

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Introduction, Background

Life expectancy increased in a remarkable manner in many high-income countries for more than 150 years as demographic research has demonstrated during the last 10 to 15 years (Oeppen and Vaupel, 2002; Tuljapurkar et al., 2000; Vallin and Meslé, 2009; White, 2002). Omran's theory (1971) of an "Epidemiologic Transition" with its associated change in causes of death and the ages, which are mainly affected, captures the development until the late 1960s — when the theory was formulated — very well. What was not anticipated was the "cardiovascular revolution": Unexpected strong reductions in mortality from circulatory diseases. Due to its fundamental shift away from infectious diseases towards circulatory diseases, inducing mortality reductions from younger to older ages, the concept of a second stage of a health transition—as introduced by Frenk et al. (1991)—appears to be an appropriate refinement of Omran's earlier theory (see also Meslé and Vallin, 2006b).

While the general trend is positive, not all countries have benefited equally (see Figure 1). In countries such as France, Sweden or Italy, life expectancy rose at a pace of about 2.5 years per decade. Other countries have experienced periods of stagnation — in some cases even decreases — of life expectancy followed by years of catching up. Denmark, the United States, Russia and the former GDR are most prominently discussed in the literature but also Hungary belongs to that group. Despite some similarities in life expectancy developments in the latter group, the reasons for the observed trajectories are diverse. Smoking appears to have a negative effect from a cohort perspective in Denmark and the United States; period effects such as sudden improvements in medical care and higher purchasing power are typically brought forward to explain the rapid increase in life expectancy in the former GDR after reunification (e.g., Christensen et al., 2010; Crimmins et al., 2010, 2011; Jacobsen et al., 2002; Shkolnikov et al., 2013; Vogt, 2013; Wang and Preston, 2009).

Our approach

The goal of our paper is to present a tool, which allows to easily visualize these mortality dynamics. Our plots build on Lexis surface maps pioneered originally in the mid-1980s (Caselli et al., 1985; Gambill and Vaupel, 1985; Vaupel et al., 1985).[1] Instead of plotting actual death rates, our maps depict rates of mortality improvement, which are the time-derivatives of age-specific death rates. Kannisto et al. (1994) introduced average rates of improvement. While our approach is similar, we differ from Kannisto et al. (1994) in three aspects: First, we use a continuous time version of Kannisto's equation.[2] Second, we use single ages instead of large age-groups. Third, instead of reporting numerical values, we (obviously) plot those values. We think that those maps provide better insights into mortality dynamics than standard surface maps but are equally intuitively understandable.

[1] Caselli et al. (1985) point out that the first demographic surface map has been created by Delaporte in 1941.

[2] The basis for Kannisto's estimates of the rate of change ρ is $m(x, t+\delta) = m(x,t) \times (1+\rho)^{\delta}$; we use $m(x, t+\delta) = m(x,t)e^{\rho\delta}$ with $\delta = 1$.

Mortality Surface Maps in General

The left panel of Figure 2 on page 8 shows the distribution of death counts by single year (1950–2010) and age (0–100) for US women. In the middle panel of Figure 2 those death counts have been divided by their respective exposures to obtain death rates. Assuming a Poisson distribution (Brillinger, 1986), these death rates have been smoothed in the right panel with the *P*-spline approach of Eilers and Marx (1996) using the package "MortalitySmooth" by Camarda (2009; 2012). The same colors correspond to the same levels of mortality, accentuated by three contour lines.

Surface Maps of Rates of Mortality Improvement

While the colors and the upward trends of the contour lines already suggest that mortality is decreasing, there are debates about how mortality has changed. Were period or cohort effects more instrumental? Plotting the rates of mortality improvement (see Figure 3, page 9) allows some answers without the identification problem of Age-, Period-, Cohort-Analysis. White areas denote age-specific death rates, which remained constant over time. Increasingly darker shades of grey indicate worsening survival. Blue and green colors show slight and moderate mortality improvements, respectively. Rapid mortality declines are illustrated by red, orange, and yellow. The aspect ratio of the figure has been chosen in a way that one calendar year is the same length as one age year. Consequently, cohort effects correspond to patterns on the 45 degree line. Mortality for women in the US seems to have a multitude of influences. In the 1970s, remarkable improvements in mortality were observed at virtually all ages, i.e. a strong period effect. The minor increases in life expectancy between 1980 and 2000 were influenced by some cohort patterns in grey.

Maps for Causes of Death

We decided to investigate this pattern deeper by analyzing causes of death. Data on causes of death from the National Center for Health Statistics are available from 1959 until 2010 and can be downloaded from the National Bureau of Economic Research (National Center for Health Statistics, 2013). The coding of causes, in particular across the ICD revisions 8, 9, and 10 was based on the schemes published in Janssen et al. (2004) and Meslé and Vallin (2006a). The largest number of deaths are attributed to circulatory diseases. Our surface maps of rates of mortality improvement for this category are shown in Figure 4 (p. 10) for women and in Figure 5 (p. 11) for men. One thing appears to be obvious: If circulatory diseases had been the major driving force of mortality in the United States, there would have not been any stagnation. Strong period effects in the 1970s and since 2000 are clearly visible. It can be debated whether we can see a cohort effect from 1980 until 2000 or a period effect slightly distorted by a cohort effect at ages 30 to 50. The largest single cause, ischaemic heart disease (Figures 6 and 7 on pages 12–13), appears to be the main determinant for the development of all circulatory diseases.

Another advantage is also illustrated by these figures: Problems in the raw data or in the reconstruction become easily visible as indicated by the vertical line in 1979/1980 and slightly less in 1967/1968.

Clear cohort patterns can be observed for malignant neoplasms as shown in Figures 8 (p. 14) and 9 (p. 15) for women and men, respectively. It has been argued that cohort smoking histories are a major determinant for life expectancy changes and that the slow increase in life expectancy among women in the US but also in Denmark is/was a consequence of the high smoking prevalence of females in those countries (e.g., Crimmins et al., 2010, 2011; Jacobsen et al., 2002; Juel, 2000; Preston and Wang, 2006; Wang and Preston, 2009). This perspective is strikingly supported when plotting rates of mortality improvement for lung cancer, the cause of death most severely affected by smoking, in Figures 10 (p. 16) and 11 (p. 17). One can see the same pattern as for all cancers combined; the severity is considerably stronger, though.

Obesity is besides smoking another lifestyle factor cited to have had a dampening influence on life expectancy in the US (e.g., Crimmins et al., 2011). The cause of death, which might have a close link to obesity is diabetes. The corresponding rates of mortality improvement for women and men are illustrated in Figures 12 (p. 18) and 13 (p. 19). While a strong period effect had a substantial negative influence from the mid-1980s until the end of the 1990s, the green, red, and even yellow colors at the end of our observation period suggest that the situation might improve again.

Next steps

In the next steps we will analyze more causes of death, for instance, selected cancers, respiratory diseases such as pneumonia or asthma, and other causes to obtain a more complete understanding of US mortality dynamics since the 1960s.

Depending on the availability of data, our aim is to extend the analysis by cause of death to European countries. This will allow us to gain a deeper understanding how mortality has changed in several European countries in a comparative perspective. As shown in Figure 1, the general pattern of life expectancy development for women in the United States and in Denmark is shared with Hungary (albeit on a lower level). Figure 14 for mortality from all causes indicates that a comparable trajectory of life expectancy can not be equated with the same underlying mortality dynamics. The periods of stagnation and catching up were determined by different effects in the United States (left panel), Denmark (middle panel) and Hungary (right panel). The newly started Project DIMOCHA, funded by the national science foundations of France and Germany, will possibly provide such a database containing the required detailed cause-of-death information.

Acknowledgments:

The European Research Council has provided financial support under the European Community's Seventh Framework Programme (FP7/2007-2013) / ERC grant agreement no. 263744.

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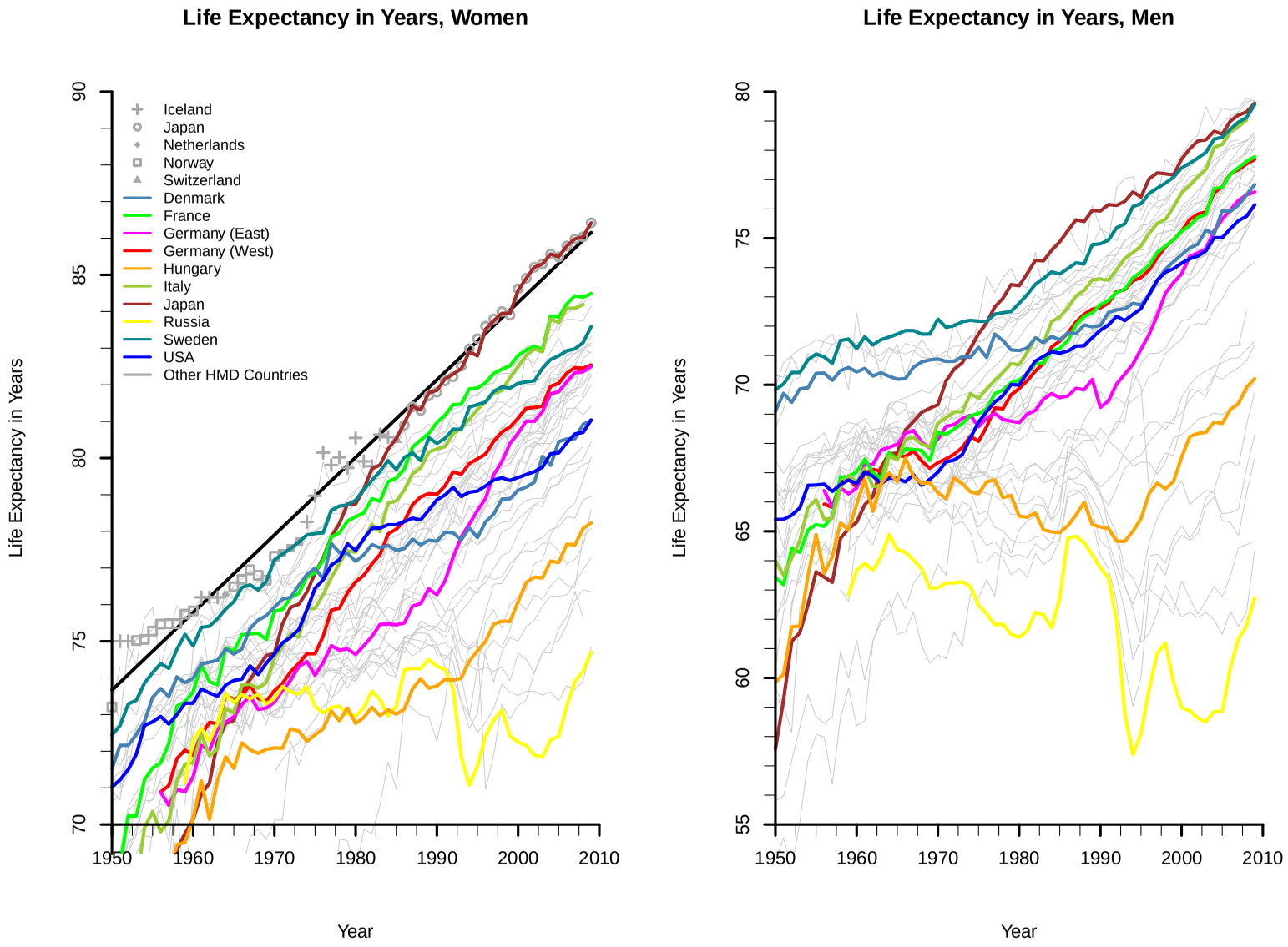

Figure 1: Life Expectancy among Women (Left Panel) and Men (Right Panel) in Selected Countries of the Human Mortality Database. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013).

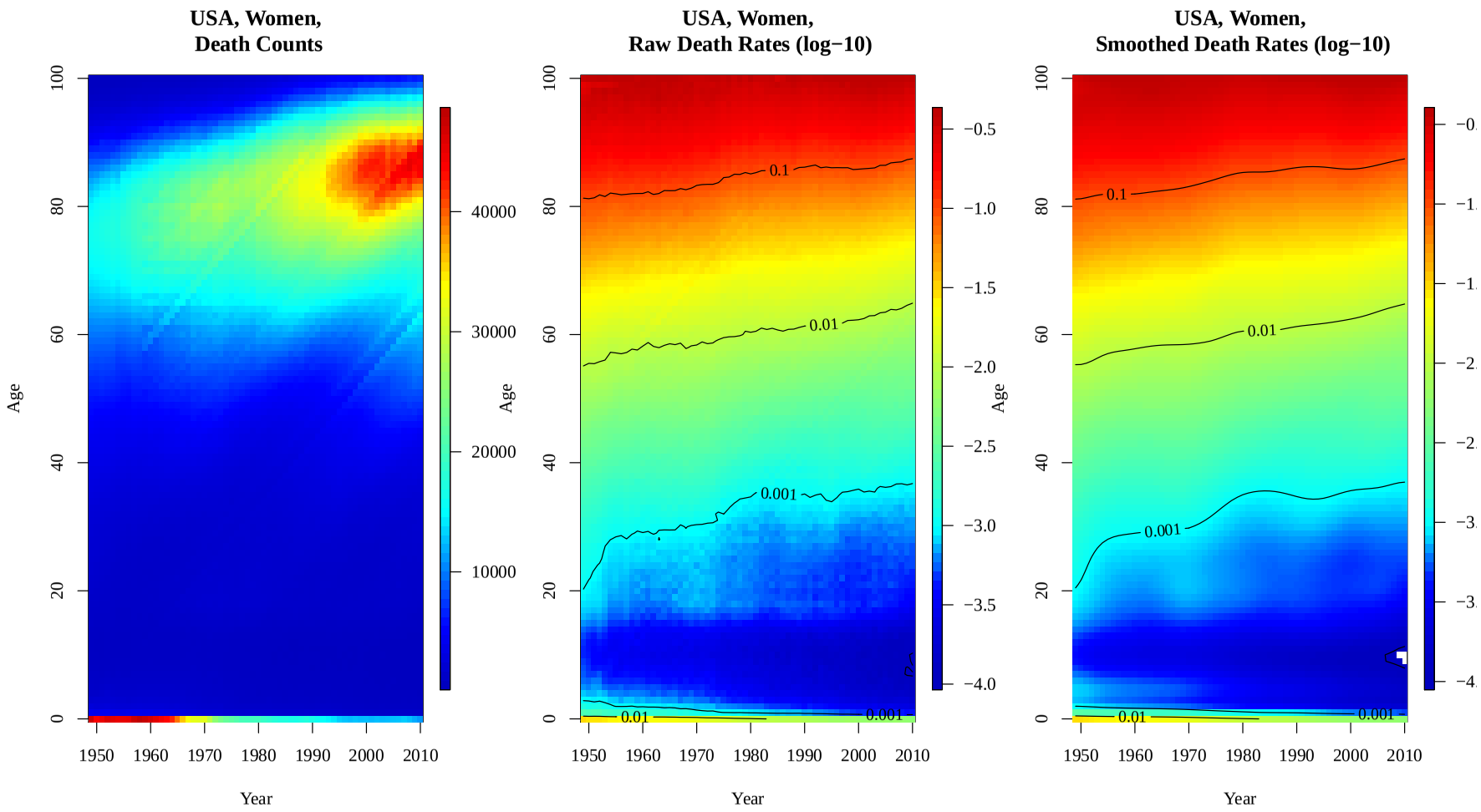

Figure 2: Counts, Raw Rates and Smoothed Rates for US Women by Single Year and Age. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013).

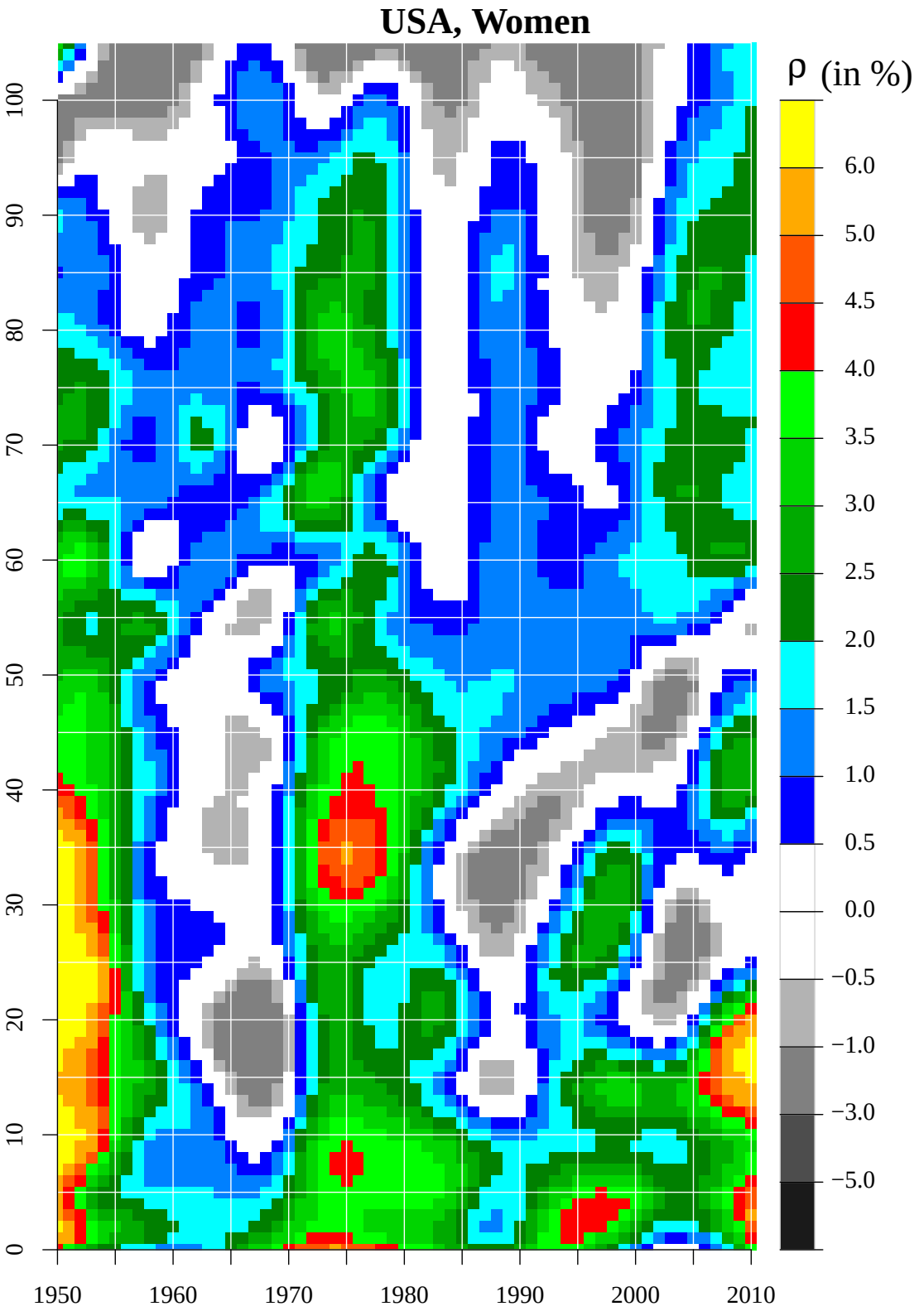

Figure 3: Rates of Mortality Improvement for US Women. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013).

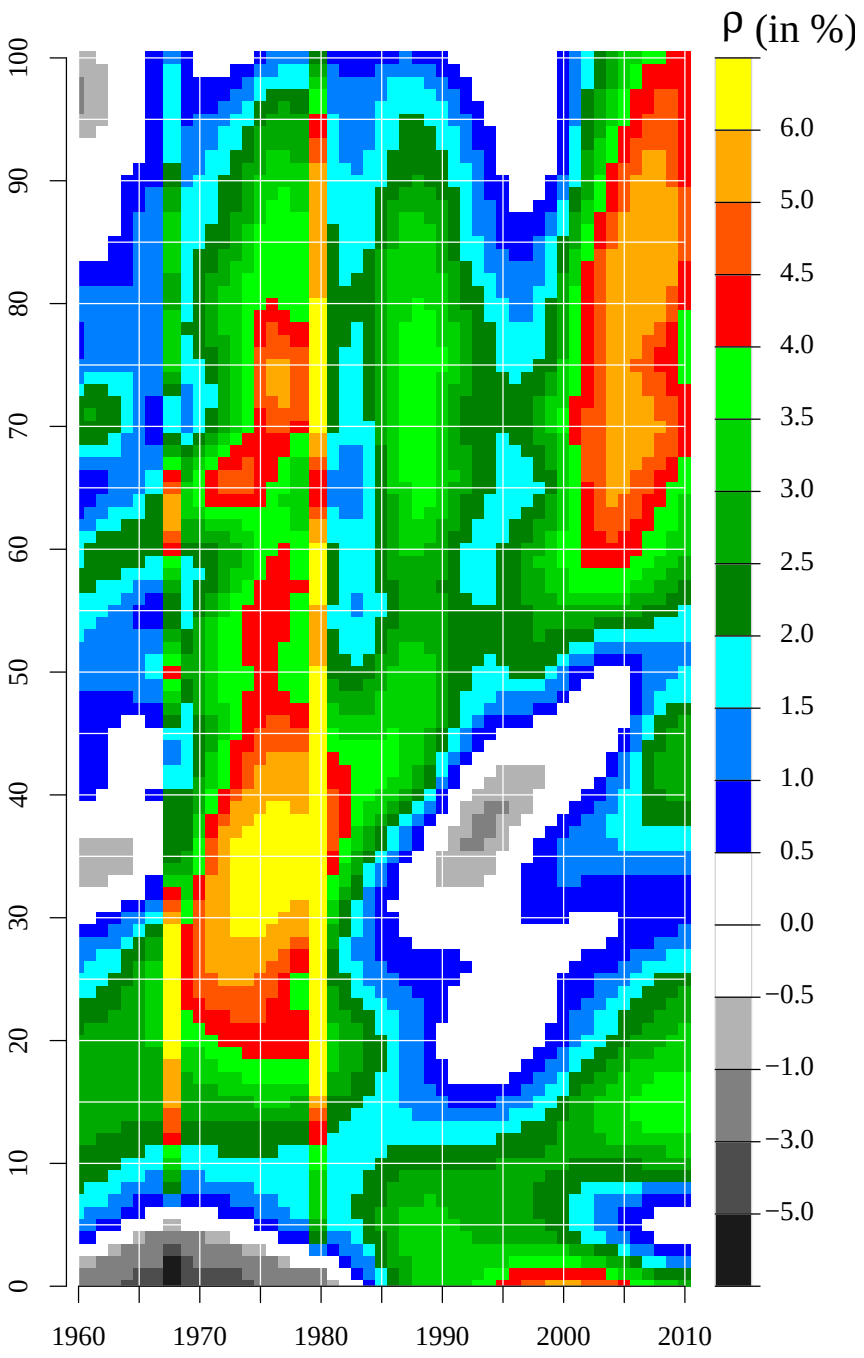

Figure 4: All Circulatory Diseases, Rates of Mortality Improvement for US Women. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

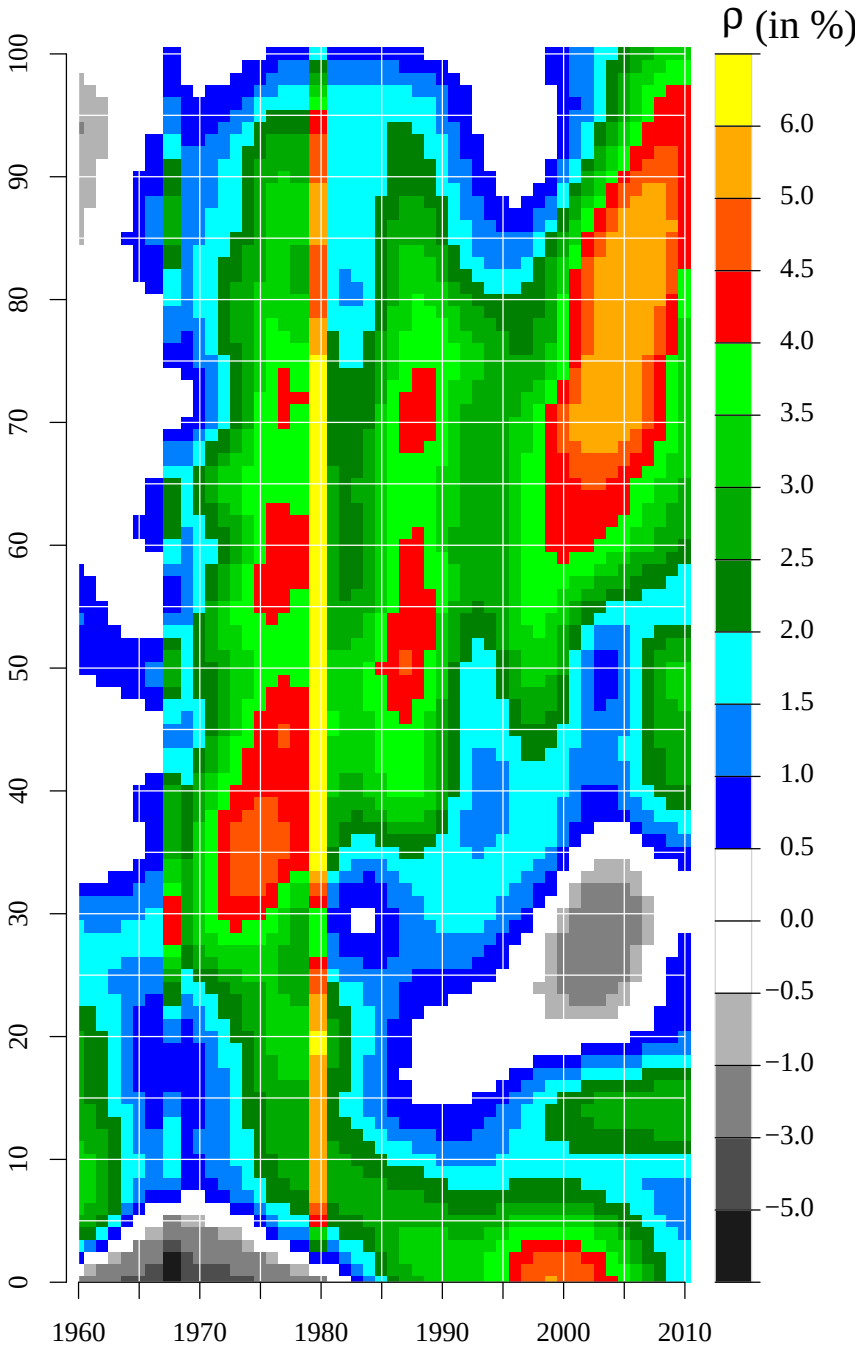

Figure 5: All Circulatory Diseases, Rates of Mortality Improvement for US Men. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

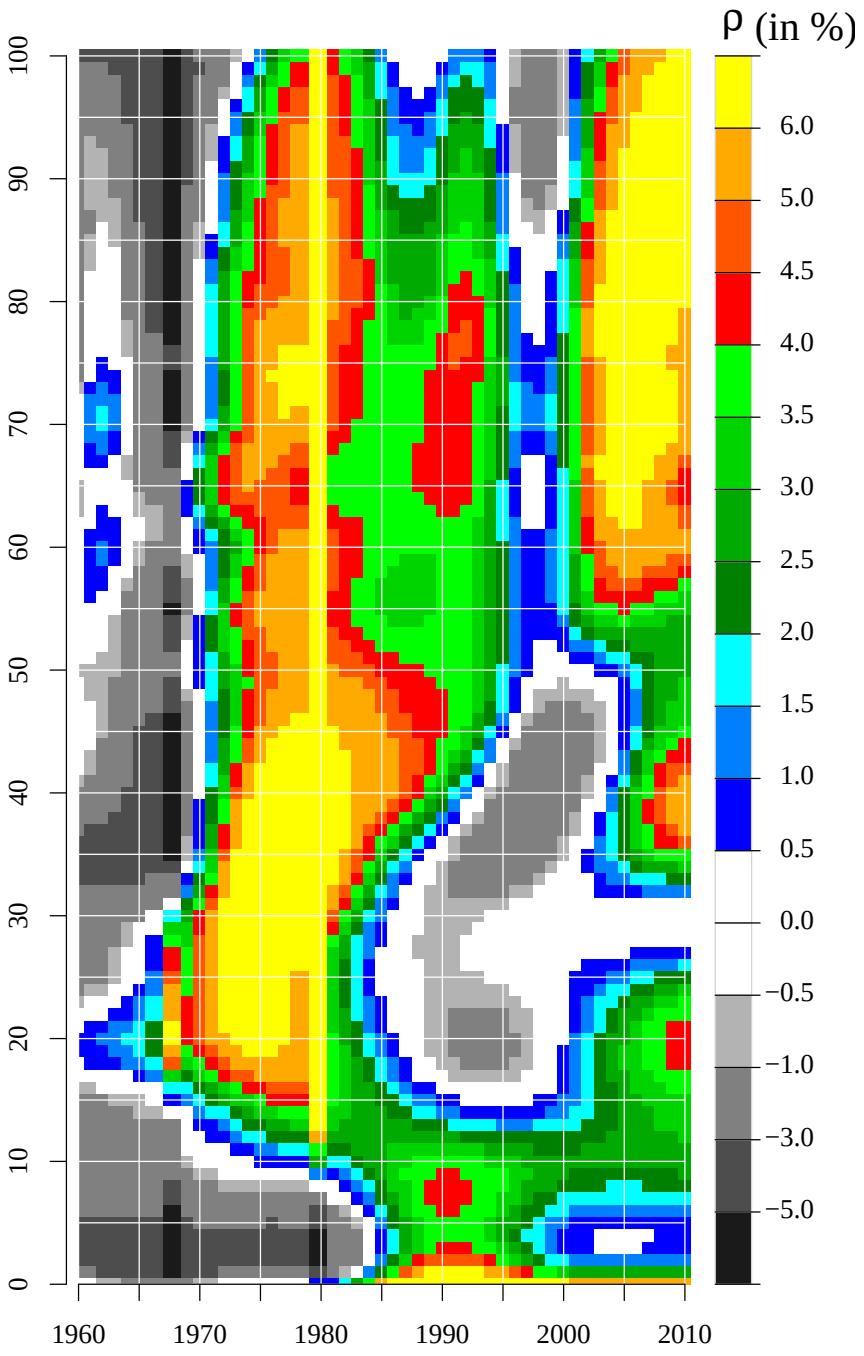

Figure 6: Ischaemic Heart Disease, Rates of Mortality Improvement for US Women. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

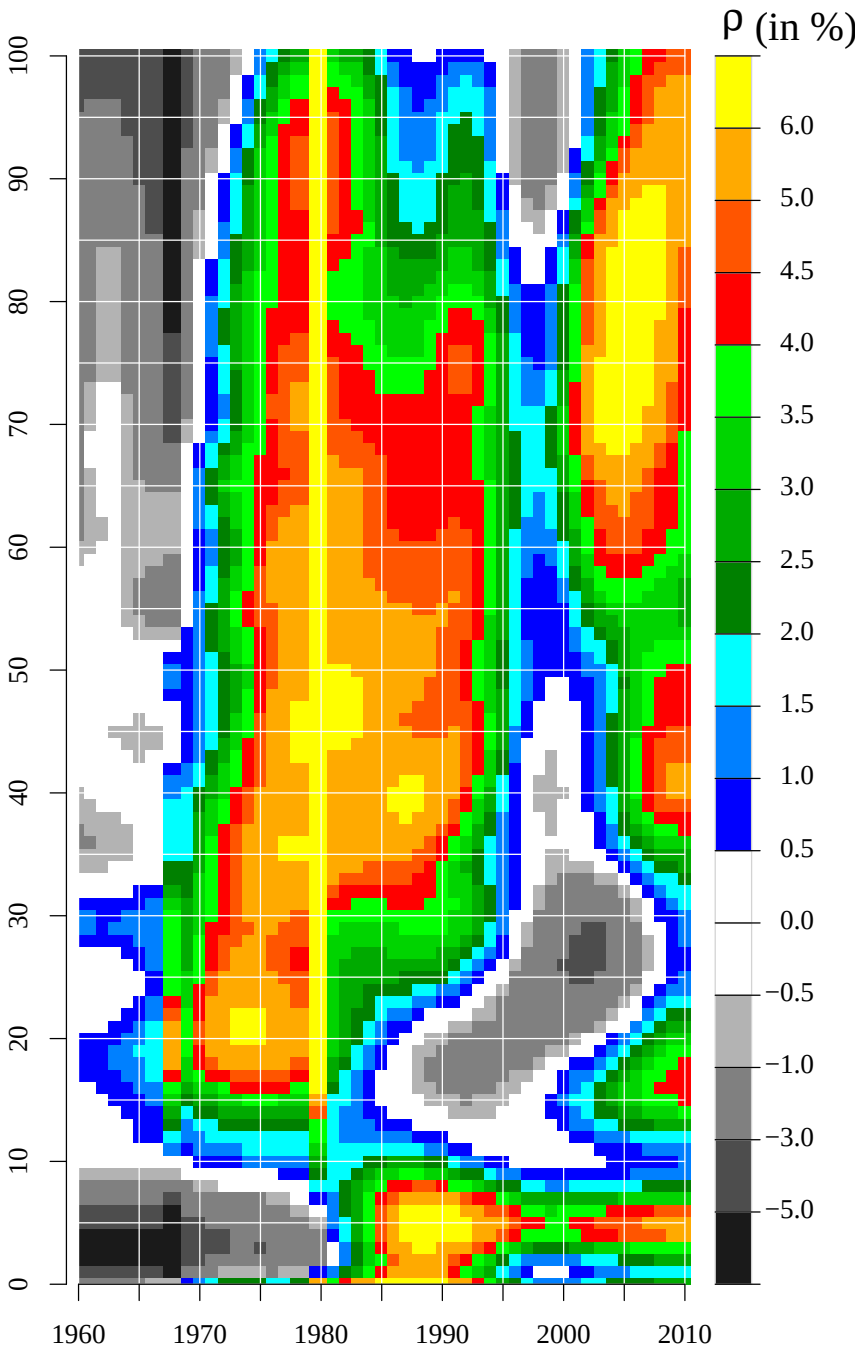

Figure 7: Ischaemic Heart Disease, Rates of Mortality Improvement for US Men. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

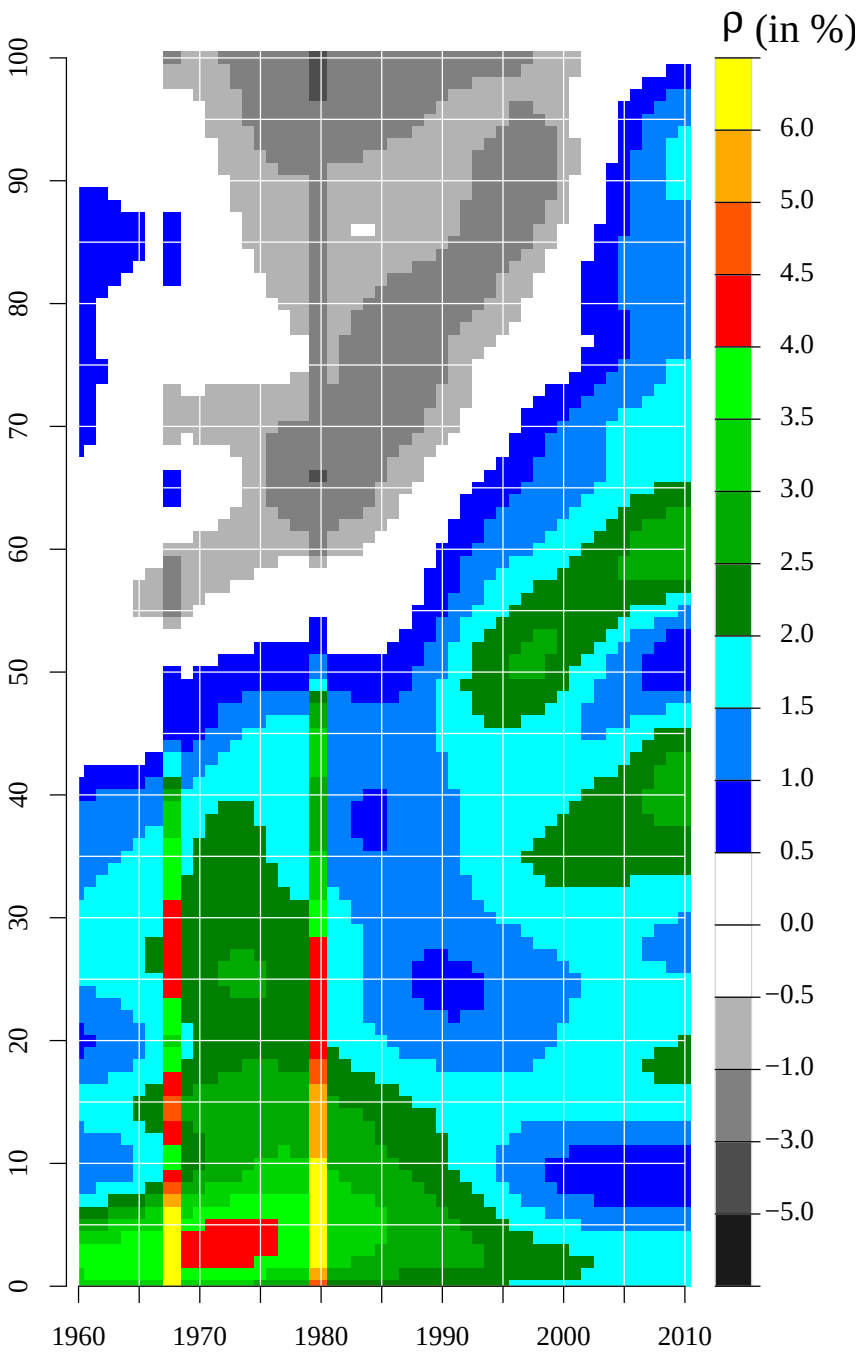

Figure 8: All Malignant Neoplasms (Cancer), Rates of Mortality Improvement for US Women. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

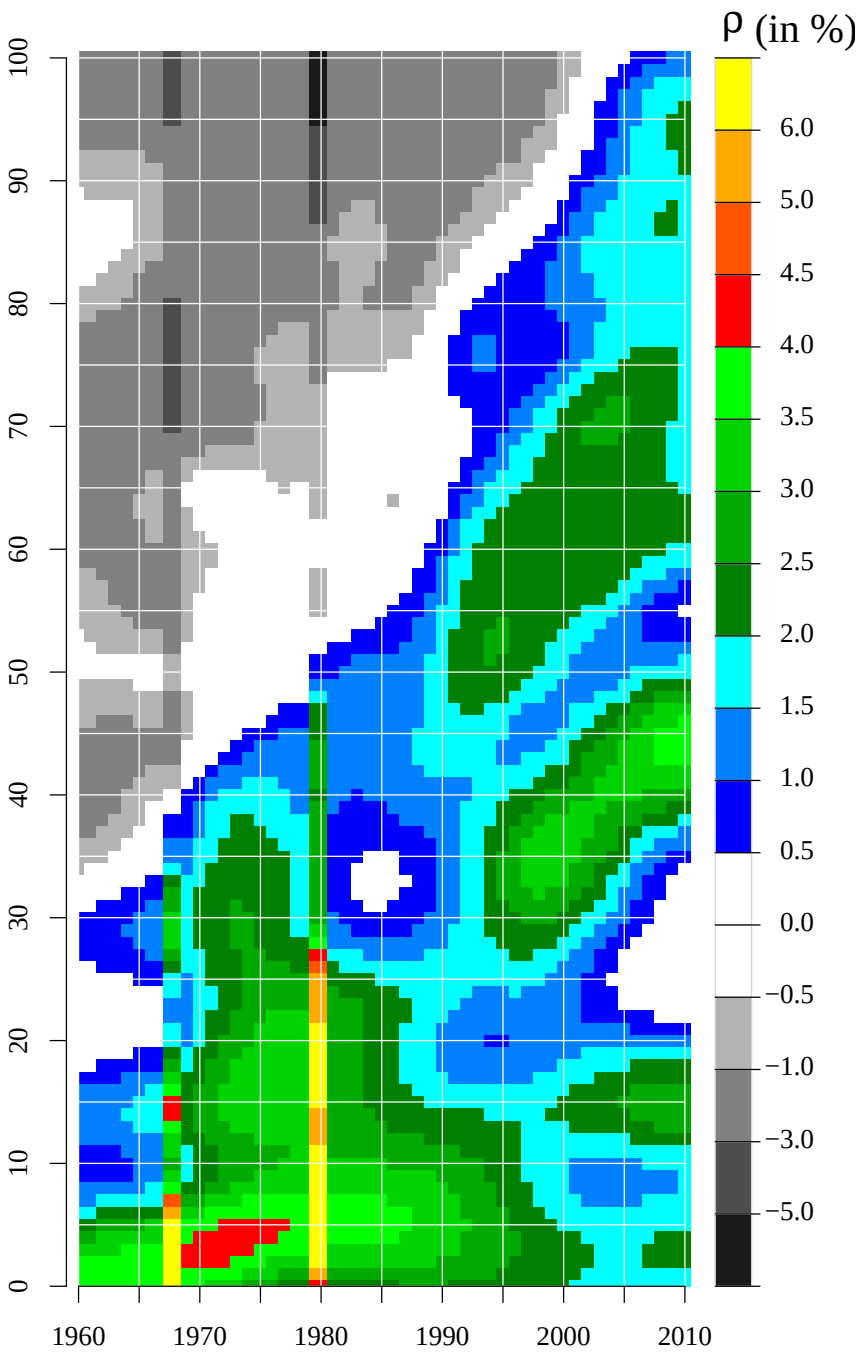

Figure 9: All Malignant Neoplasms (Cancer), Rates of Mortality Improvement for US Men. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

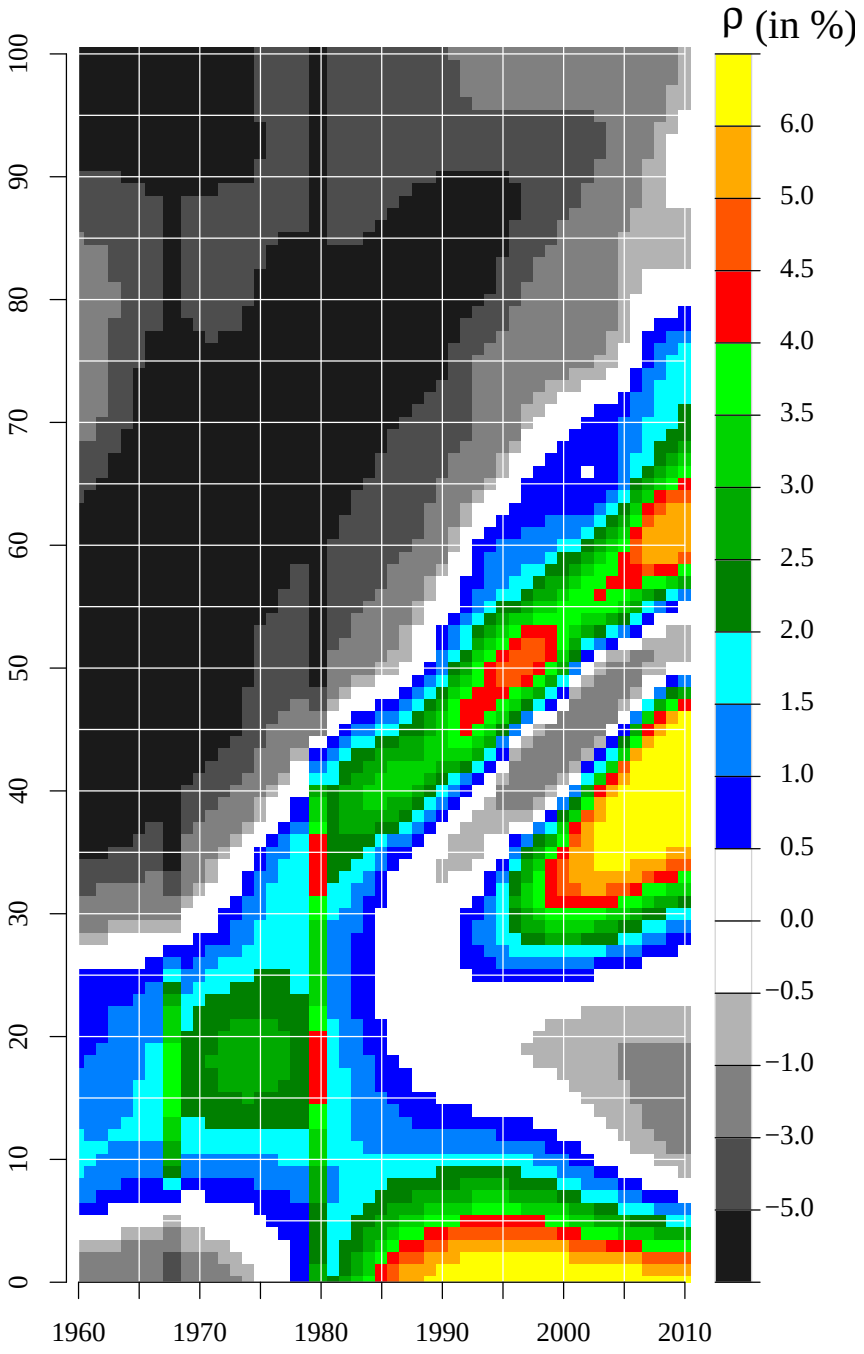

Figure 10: All Malignant Neoplasms (Cancer), Rates of Mortality Improvement for US Women. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

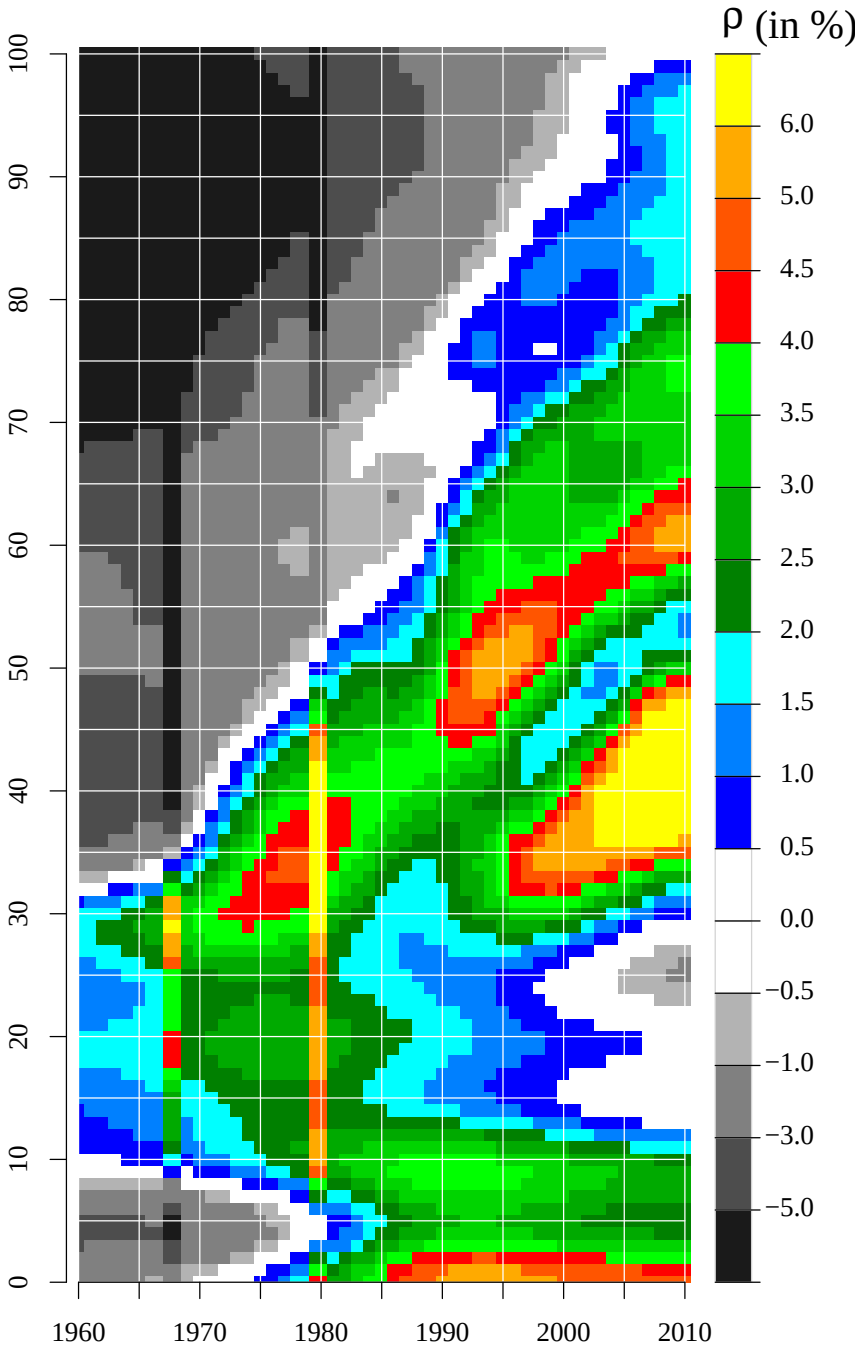

Figure 11: All Malignant Neoplasms (Cancer), Rates of Mortality Improvement for US Men. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

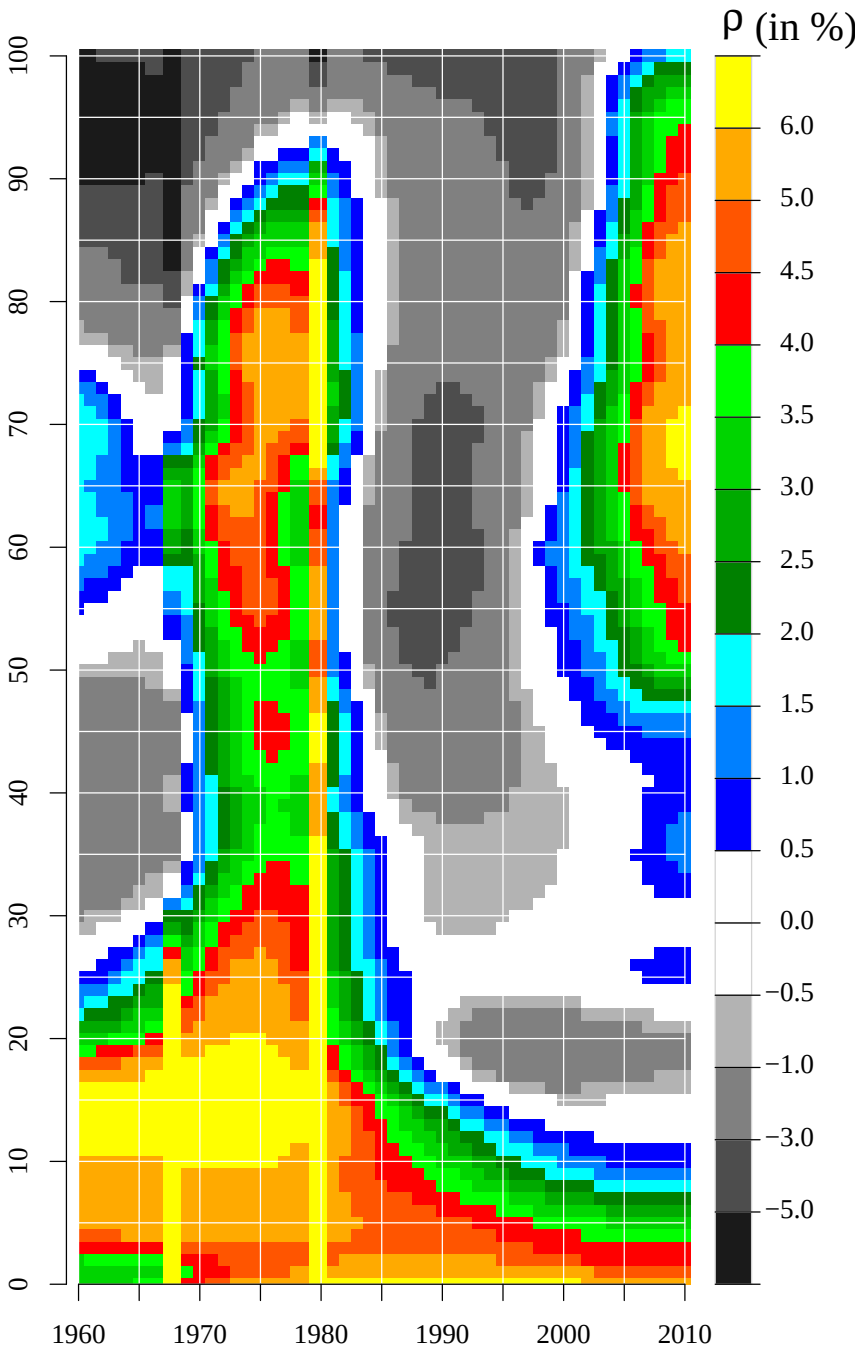

Figure 12: All Malignant Neoplasms (Cancer), Rates of Mortality Improvement for US Women. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

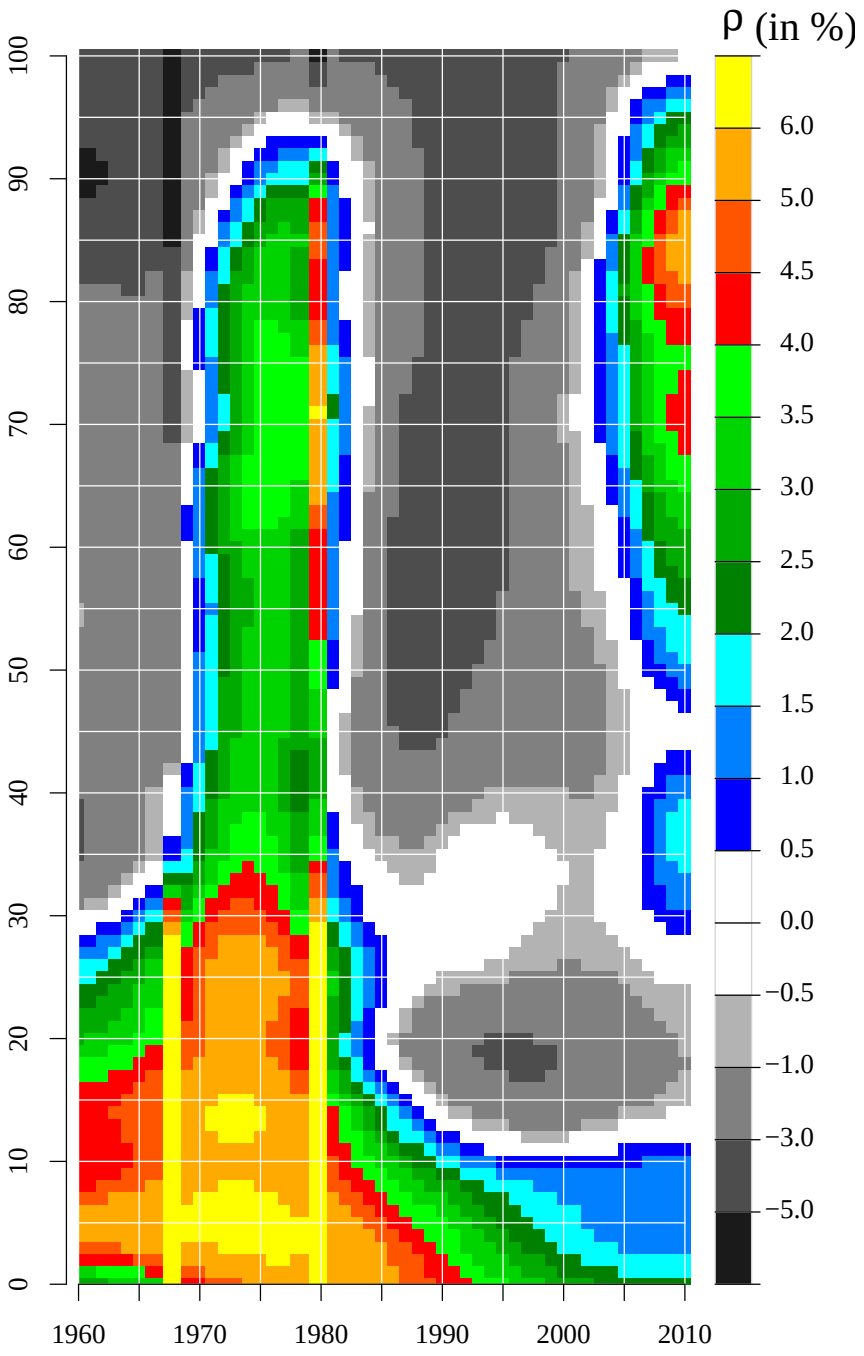

Figure 13: All Malignant Neoplasms (Cancer), Rates of Mortality Improvement for US Men. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013) and NCHS's Multiple Cause of Death Data (2013).

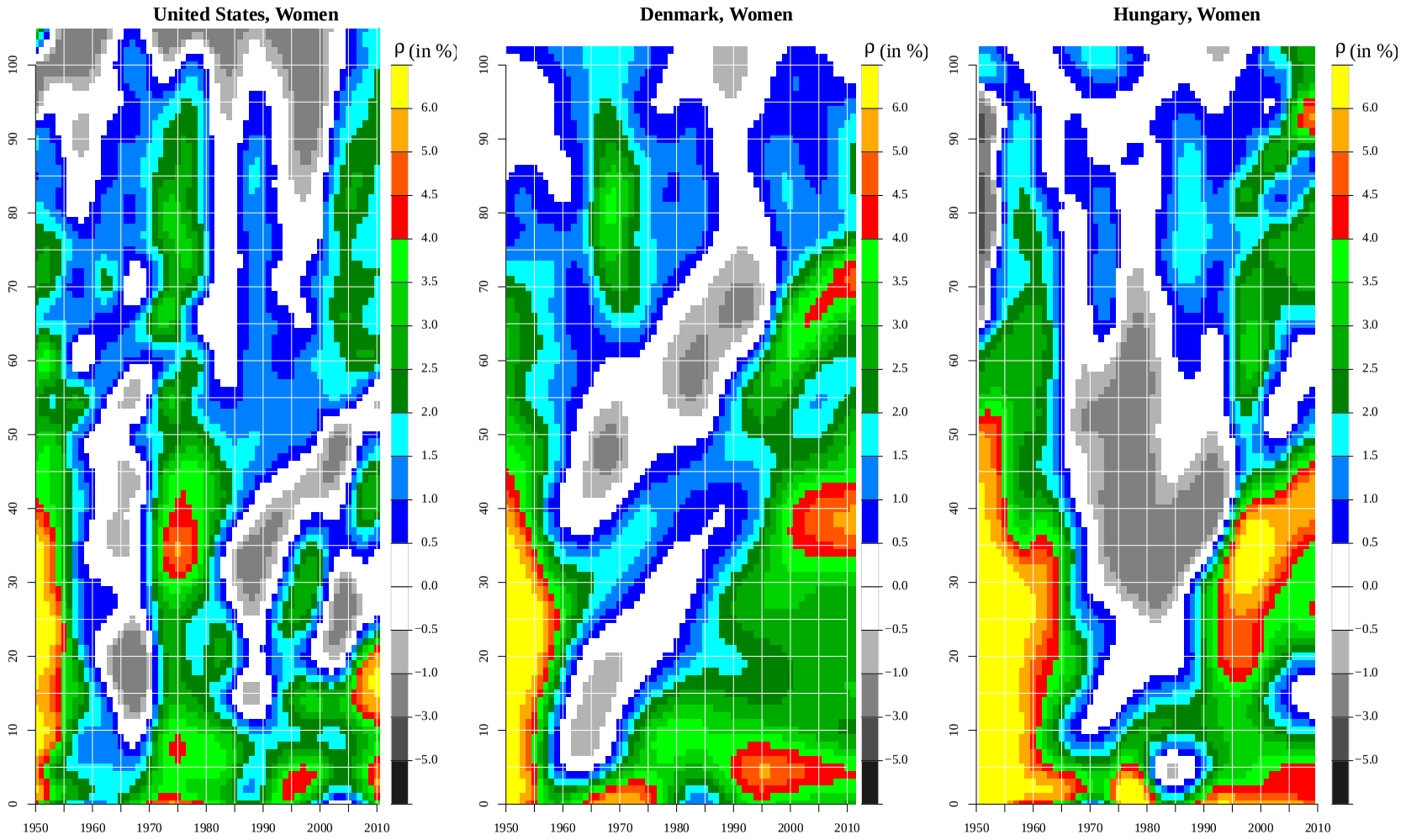

Figure 14: Rates of Mortality Improvement for Women in the United States, Denmark and Hungary. Source: Illustration of the Authors Based on Data from the Human Mortality Database (2013).