Period or Cohort Effects?
Surfaces of Average Annual Improvements in Mortality
Extended Abstract

Roland Rau[1,2] Magdalena Muszyńska[3]

[1] University of Rostock, Germany

[2] Max Planck Institute for Demographic Research, Germany

[3] Duke University, NC, USA

September 21, 2009

Abstract

What drives mortality change? While some argue that current conditions shape mortality (period effects), other propose that events early in life or the cumulative experience throughout life determines mortality (cohort effects). The novelty of our study is to approach this question by Lexis surface maps of average annual improvements in mortality. Our result is that within the countries from the Human Mortality Database, there is no uniform pattern which shaped the development of mortality in recent decades. For instance, the former Eastern part of Germany experienced strong positive period effects since reunification in 1990 whereas Russia suffers from negative period effects already for several decades. Life expectancy of Danish women stagnated for almost 20 years after 1980 due to strong effects of birth cohorts born between the two World Wars. In contrast, we found also strong positive cohort effects of women and men born around 1940 in several countries.

Keywords: Mortality Differentials; Lexis-Grid; Age-, Period-, Cohort-Effects

Introduction

The twentieth century has seen unprecedented improvements in survival. Not only record life expectancy has been increasing (from 60 years in New Zealand in 1900 to 86 years nowadays in Japan) but also life expectancy in most developed countries (Oeppen and Vaupel, 2002; Tuljapurkar et al., 2000; White, 2002; Wilmoth, 1998).

But what drives mortality change? Are current conditions responsible for the observed improvements in survival? Or are factors such as early childhood conditions — possibly even in utero — or smoking histories the main determinants for mortality later in life? This question is currently highly debated in demography and related disciplines (see, for instance, Barbi and Vaupel, 2005; Barker, 1995; Finch and Crimmins, 2004; Preston and Wang, 2006; Vaupel et al., 2003; Wang and Preston, 2009).

However, it is not only of academic interest but has also essential implications for public policy. As Elo and Preston (1992, p. 186) write: "If ill health among adults is to an important extent a carryover of ill health in childhood, then health programs need to be calibrated accordingly."

The Age-Period-Cohort-framework provides a useful framework to analyze such questions (Wilmoth, 1990, 2006). The major methodological problem is the so-called *identification problem*: since `Period=Cohort+Age` it is impossible to attribute a change in a variable of interest (e.g. death rates) correctly to the the three variables age, period, and cohort. Wilmoth (2006, p. 235) writes: "there is no magic solution". We try to circumvent this problem by plotting maps of Lexis surfaces as pioneered by Caselli et al. (1985), Gambill and Vaupel (1985), or Vaupel et al. (1985). Nathan Keyfitz already pointed out in the foreword to Vaupel et al. (1985) that such maps can be used for questions such as "[w]hether mortality improvement takes place by cohorts or by periods."

Figure 1 (page 9) gives an overview how age-, period-, and cohort-effects would ideally look like on the Lexis-surface. The same color indicates the same value in the variable of interest (e.g. death rates). The left panel represents "pure" age-affects. That means that the only variation in the variable of interest takes place across the age-dimension. The panel in the middle denotes "pure" period effects, i.e. the same values are measured across all ages but they differ along the calendar time/period dimension ("Year"). Finally, the panel on the right illustrates how a surface map would look like if (birth) cohorts alone were driving the development in the variable of interest. The same color along the 45°-line shows that each cohort has their own characteristic value of the variable of interest which does not change throughout their life-course. Of course, those representations are simplified and we expect to find rather interactions of these three forces than such "pure" effects.

Data & Method

Data Our analysis is based on death counts and their corresponding exposures by single ages and calendar years to estimate death rates. All of our data have been obtained from the Human Mortality Database (2009).

Method To avoid spurious conclusions due to small numbers, we smoothed the death rates in a first step. We chose the smoothing method as presented by Currie et al. (2004). This approach extends the one-dimensional P-spline smoothing of Eilers and Marx (1996) to two dimensions. Using data for Norwegian males, Figure 2 (page 10) gives an example how the mortality surfaces look like before and after smoothing. One can clearly see that the important characteristics of the data are still present after smoothing. Random patterns have been removed, though.

We measured developments in mortality via "average annual improvements in mortality" $\rho(x,y)$. This approach is similar to Kannisto et al. (1994):

$$\rho(x,y) = -\left(\left(\frac{m(x,y)}{m(x,y-\delta)}\right)^{\frac{1}{\delta}} - 1\right) \quad (1)$$

where $m(x,y)$ denotes (smoothed) death rates at age x in year y and δ is an arbitrary interval length. We chose $\delta = 10$.[1].

In Figure 3 (page 11), we illustrate our approach using data for women from East Germany. The left panel shows the smoothed mortality surfaces we have seen before in the right panel of Figure 2.[2] One can easily see that the contour lines are moving upwards at almost all ages after 1990, indicating a period effect. Using our measure $\rho(x,y)$ for average annual improvements in mortality in the right panel of 3 makes those developments more apparent. Each square by single year and age compares mortality at this age and year with mortality $\delta = 10$ years earlier. For instance, the bright green square in the year $y = 1966$ at age $x = 17$ denotes that mortality dropped on average 2.0–2.5 percent *every* year between y and $y - \delta = y - 10 = 1956$ at age x. Blue shades have been chosen to plot improvements between 0 and 2 percent per annum, various greens for the interval from 2 to 4 percent. Even faster improvements are given in red. If conditions worsened and mortality increased over time we chose grey colors. Darker shades of grey represent worse survival situations.

[1]Equation 1 itself is only a simple reformulation and rearrangement of the "discrete growth equation" $N_t = N_0(1+x)^t$ given in almost every demography textbook, e.g. Keyfitz and Caswell (2005).

[2]We chose East-Germany in Fig. 3 because of its clearly visible effects. The choice of Norway in Fig. 2 was based on the country's small population size.

Software The analysis, including plotting, has been conducted using the R-Language (2008).

Results

We estimated surfaces of average annual improvements for all countries of the Human Mortality Database, separately for women and men. Here we present only selected countries but the plots of the remaining countries can be obtained from the authors.

We did not find a universal pattern of mortality change in the countries we analyzed. We detected strong signs for period effects as well as for cohort effects. One can also not generalize and say that period effects are typically connected with survival improvements and cohort effects with worsening conditions.

Therefore we would like to give examples for all of them. The right panel of Figure 3, showing average annual improvements for women from (former) East Germany, has already been introduced. It is an example for strong (positive) period effects. From the mid-1960s until 1990, we can see – as indicated by the blue colors – that improvements in survival were rather modest for most parts of the age-range. With re-unification in 1990, death rates started to drop dramatically, resulting in a "catch-up" period of East-German life expectancy to West-German levels. Survival improved at some ages (childhood, age 30, retirement age) even faster than at others. If the rates at those selected ages persisted, death rates could be halved within 15 years.[3]

The change in the political regime brought also positive period effects to Spain. As shown in Figure 4 (page 12) for Spanish women, death rates began to fall at almost all ages after the end of the Franco regime in 1975.

Period effects are not necessarily associated with improvements in mortality as Figures 5–7 (pages 13–15) for Russia and the two former members of the Soviet Union, Belarus and the Ukraine, show. The figures show that death rates did not begin to increase since the fall of the "iron curtain" at almost all ages for men in those three countries. The negative trend started already at the beginning of our time window and has been only shortly interrupted in the mid 1980s — probably due to Gorbachev's anti-alcohol campaign, begun in May 1985.

The surprisingly slow increase in life expectancy of Danish women since the early 1980s

[3] Assuming $\rho = 0.045 = 4.5\% : (1 - 0.045)^{15} = 0.5012456$.

has been attributed to high smoking prevalence of women born between the two World Wars (see, for instance, Jacobsen et al., 2002). This cohort effect is also strongly visible in our data as illustrated by Figure 8 (page 16). We can even see that stagnation or increases in mortality did not start in the 1980s. Already in 1970, survival was worsening (in comparison to 10 years earlier) for women aged 40–50 years, i.e. the birth cohorts born between 1920 and 1930. The shape of the grey colors along the 45°-line clearly supports the cohort effect hypothesis.

Also life expectancy for females in the United States almost stagnated after 1980. As we can see in Figure 9 (page 17), one can detect a (small) cohort effect, too. The stagnation, however, is more likely due to a lack of notable survival improvements across the whole age range (as shown by the blue colors). The development of mortality of males (Fig. 10 on page 18) in the United States looks different than for females (Fig. 9 on page 17). Apparently, there were strong period effects from the mid-1960s to the mid-1970s and in the early 1990s. The time-window and the involved ages suggest the negative influence of the war in Vietnam for the earlier period.

We found also positive cohort effects for several countries for females as well as for males: strong survival improvements starting at about age 40 in the year 1980. Here we only present two examples: Women in England & Wales (Fig. 11 on page 19) and Males in Finland (Fig. 12 on page 20). Since this pattern appears for both sexes and not only in one country, we can exclude country-specific explanations like in the case of Danish women. We do not know, however, what causes this pattern.

Finally, in this extended abstract, we want to present in Figure 13 (page 21) the results for Japanese females whose life expectancy is higher than of any other nation. We would argue that the rapid increase in life expectancy has been triggered by some “vanguard” cohorts. This was not a transient phenomen, though. Survival improved even further dramatically for subsequent cohorts.

References

Barbi, E. and J. W. Vaupel (2005). Comment on Inflammatory Exposure and Historical Changes in Human Life-Spans. *Science 308*(5729), 1743.

Barker, D. (1995). Fetal origins of coronary heart disease. *British Medical Journal 311*, 171–174.

Caselli, G., J. W. Vaupel, and A. I. Yashin (1985). Mortality in Italy: Contours of a century of evolution. *Genus 41*(1–2), 39–55.

Currie, I. D., M. Durban, and P. H. Eilers (2004). Smoothing and forecasting mortality rates. *Statistical Modelling 4*, 279–298.

Eilers, P. H. C. and B. D. Marx (1996). Flexible Smoothing with B-splines and Penalties. *Statistical Science 11*(2), 89–102.

Elo, I. T. and S. H. Preston (1992). Effects of Early-Life Conditions on Adult Mortality: A Review. *Population Index 58*, 186–212.

Finch, C. E. and E. M. Crimmins (2004). Inflammatory Exposure and Historical Changes in Human Life-Spans. *Science 305*(5691), 1736–1739.

Gambill, B. A. and J. W. Vaupel (1985, July). The LEXIS Program for Creating Shaded Contour Maps of Demographic Surfaces. Technical Report RR–85–94, International Institute for Applied Systems Analysis (IIASA), Laxenburg, A.

Jacobsen, R., N. Keiding, and E. Lynge (2002). Long term mortality trends behind low life expectancy of Danish women. *Journal of Epidemiology and Community Health 56*, 205–208.

Kannisto, V., J. Lauritsen, A. R. Thatcher, and J. W. Vaupel (1994). Reductions in mortality at advanced ages: Several decades of evidence from 27 countries. *Population and Development Review 20*, 793–810.

Keyfitz, N. and H. Caswell (2005). *Applied Mathematical Demography. Third Edition.* New York, NY: Springer.

Oeppen, J. and J. W. Vaupel (2002). Broken Limits to Life Expectancy. *Science 296*, 1029–1031.

Preston, S. H. and H. Wang (2006). Sex mortality differences in the United States: The role of cohort smoking patterns. *Demography 32*(4), 631–646.

R Development Core Team (2008). *R: A Language and Environment for Statistical Computing.* Vienna, Austria: R Foundation for Statistical Computing. ISBN 3-900051-07-0.

Tuljapurkar, S., N. Li, and C. Boe (2000). A universal pattern of mortality decline in the G7 countries. *Nature 405*, 789–792.

University of California, Berkeley (USA), and Max Planck Institute for Demographic Research, Rostock, (Germany) (2009). Human Mortality Database. Available at `www.mortality.org`.

Vaupel, J. W., J. R. Carey, and K. Christensen (2003). It's Never Too Late. *Science 301*, 1679–1681.

Vaupel, J. W., B. A. Gambill, A. I. Yashin, and B. A. J. (1985, July). Contour Maps of Demographic Surfaces. Technical Report RR–85–33, International Institute for Applied Systems Analysis (IIASA), Laxenburg, A.

Vaupel, J. W., W. Zhenglian, K. F. Andreev, and A. I. Yashin (1997). *Population Data at a Glance: Shaded Contour Maps of Demographic Surfaces over Age and Time.* Odense Monographs on Population Aging 4. Odense, DK: University Press of Southern Denmark.

Wang, H. and S. H. Preston (2009). Forecasting United States mortality using cohort smoking histories. *Proceedings of the National Academy of Sciences 106*(2), 393–398.

White, K. M. (2002). Longevity Advances in High-Income Countries, 1955–96. *Population and Development Review 28*, 59–76.

Wilmoth, J. R. (1990). Variation in Vital Rates by Age, Period, and Cohort. *Sociological Methodology 20*, 295–335.

Wilmoth, J. R. (1998). The Future of Human Longevity. *Science 280*, 395–397.

Wilmoth, J. R. (2006). Age-Period-Cohort Models in Demography. In G. Caselli, J. Vallin, and G. Wunsch (Eds.), *Demography. Analysis and Synthesis*, Volume I, Chapter 18, pp. 227–236. Amsterdam, NL: Elsevier.

FIGURES

Figure 1: “Ideal” Age-, Period-, and Cohort-Effects

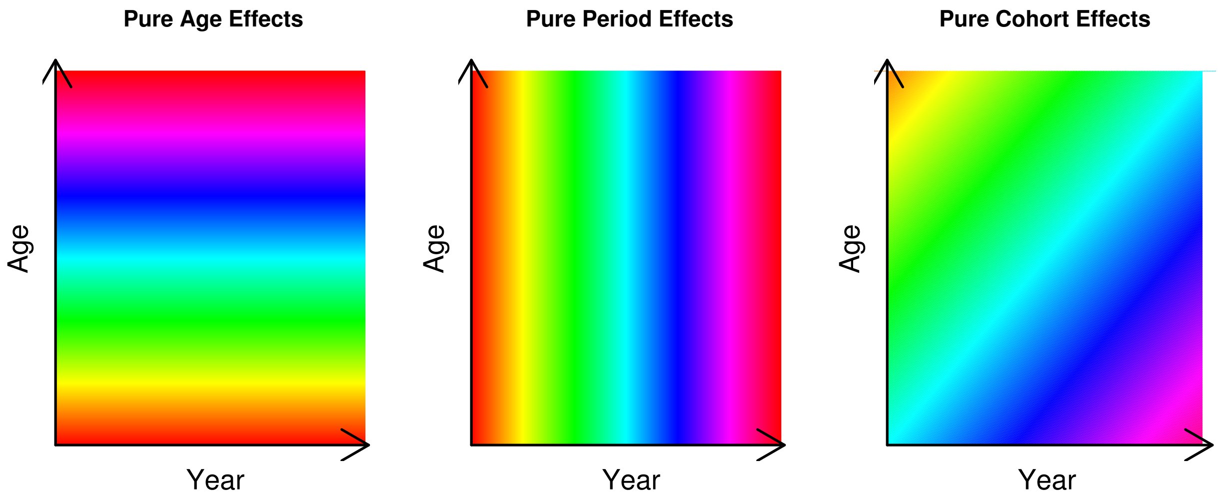
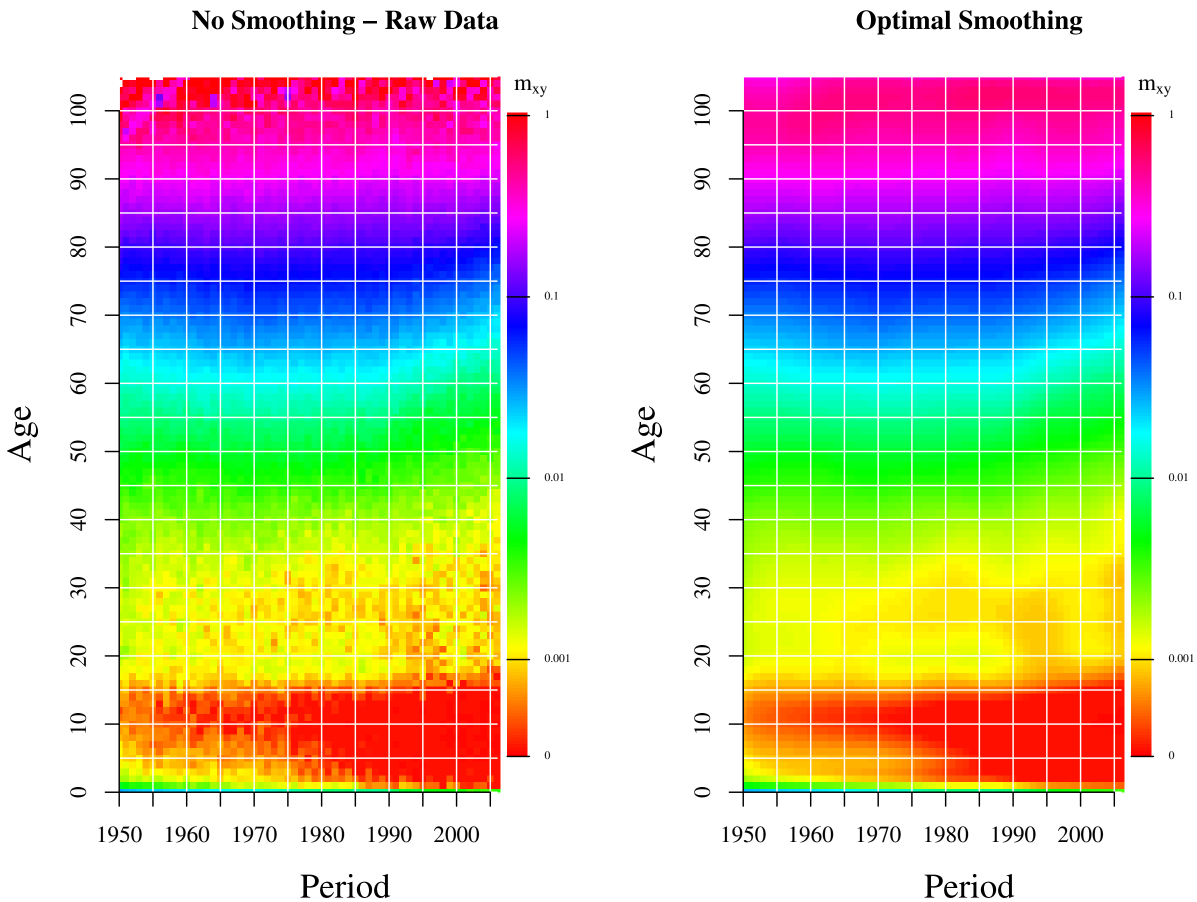


Figure 2: Raw and Smoothed Mortality Surfaces; Example: Norway, Males



"Optimal" in "Optimal Smoothing" refers to the optimal choice of the smoothing parameter vector of λs in the method of Currie et al. (2004).

Figure 3: From Mortality Surfaces to Improvement Surfaces

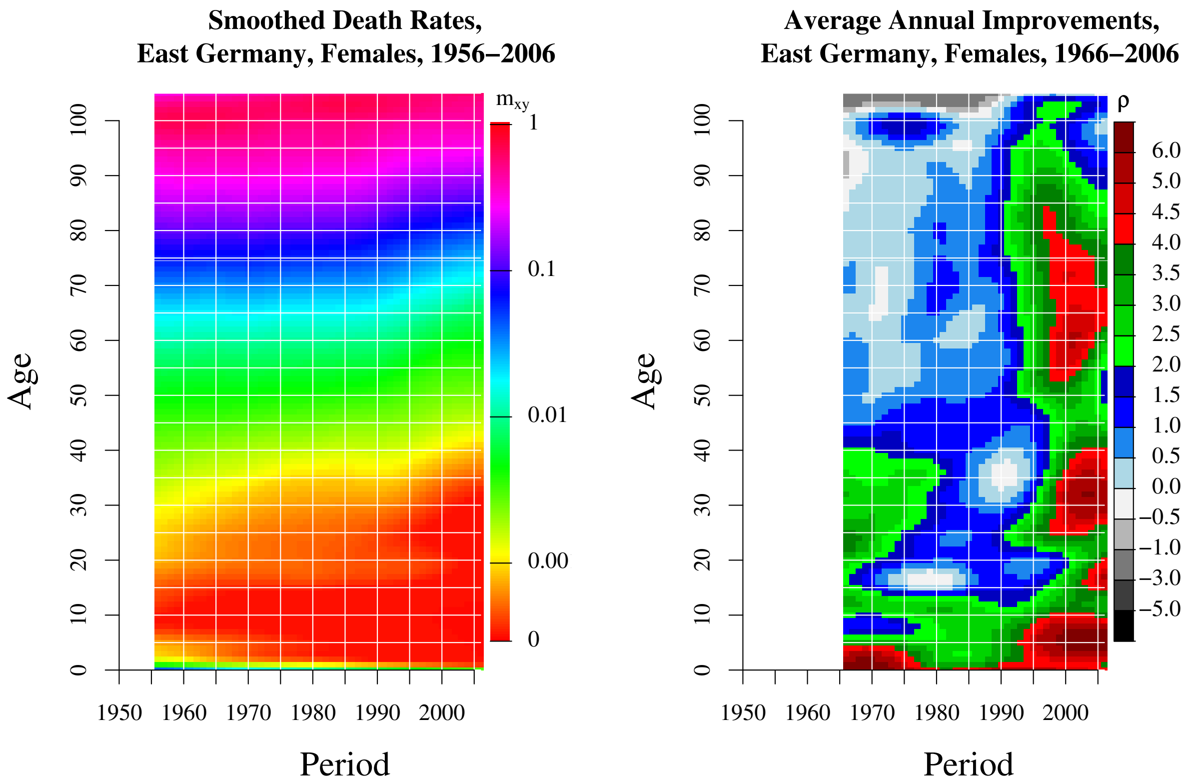


Figure 4: Average Annual Improvements in Mortality, Spain, Females

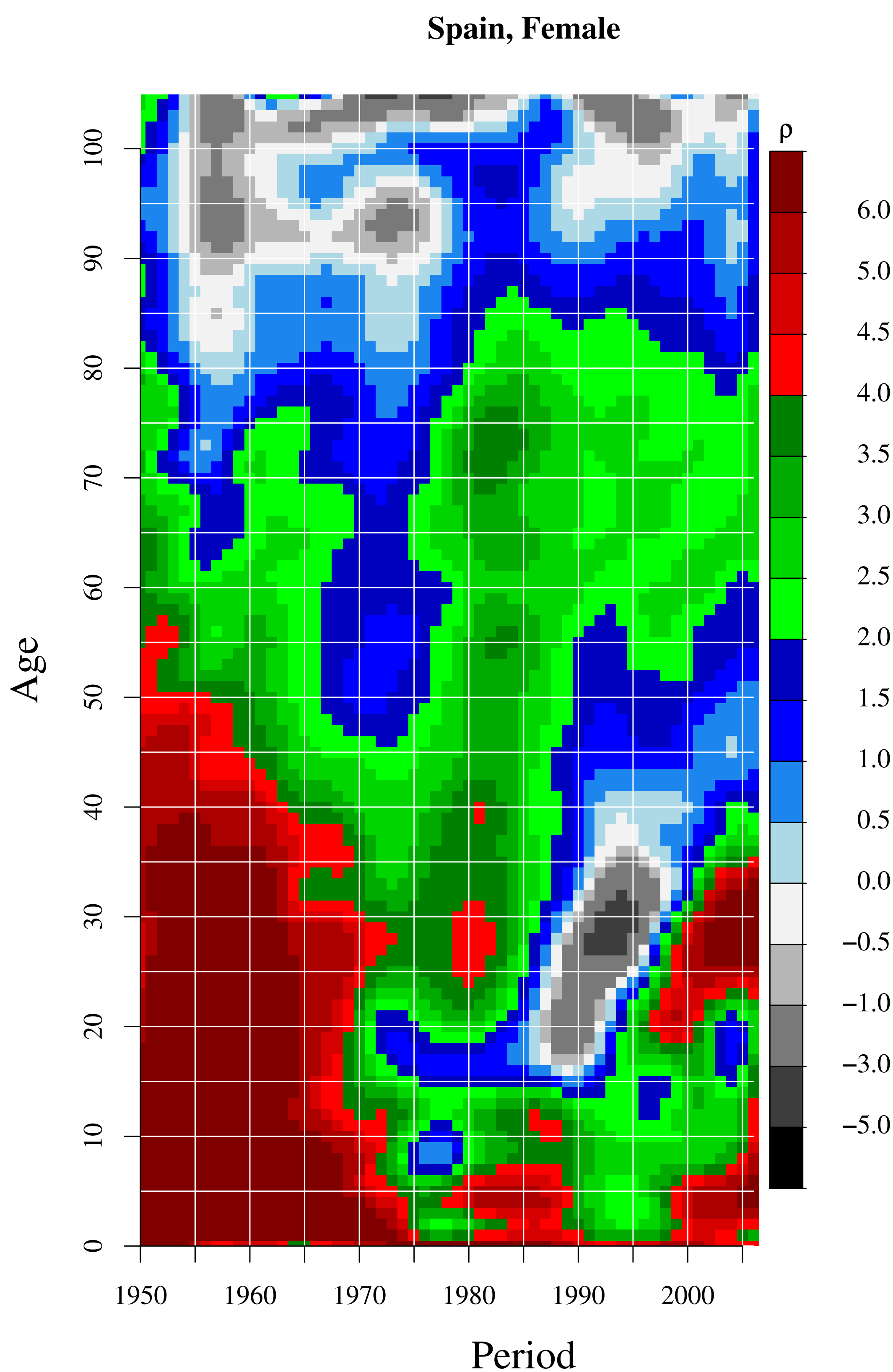


Figure 5: Average Annual Improvements in Mortality, Russia, Males

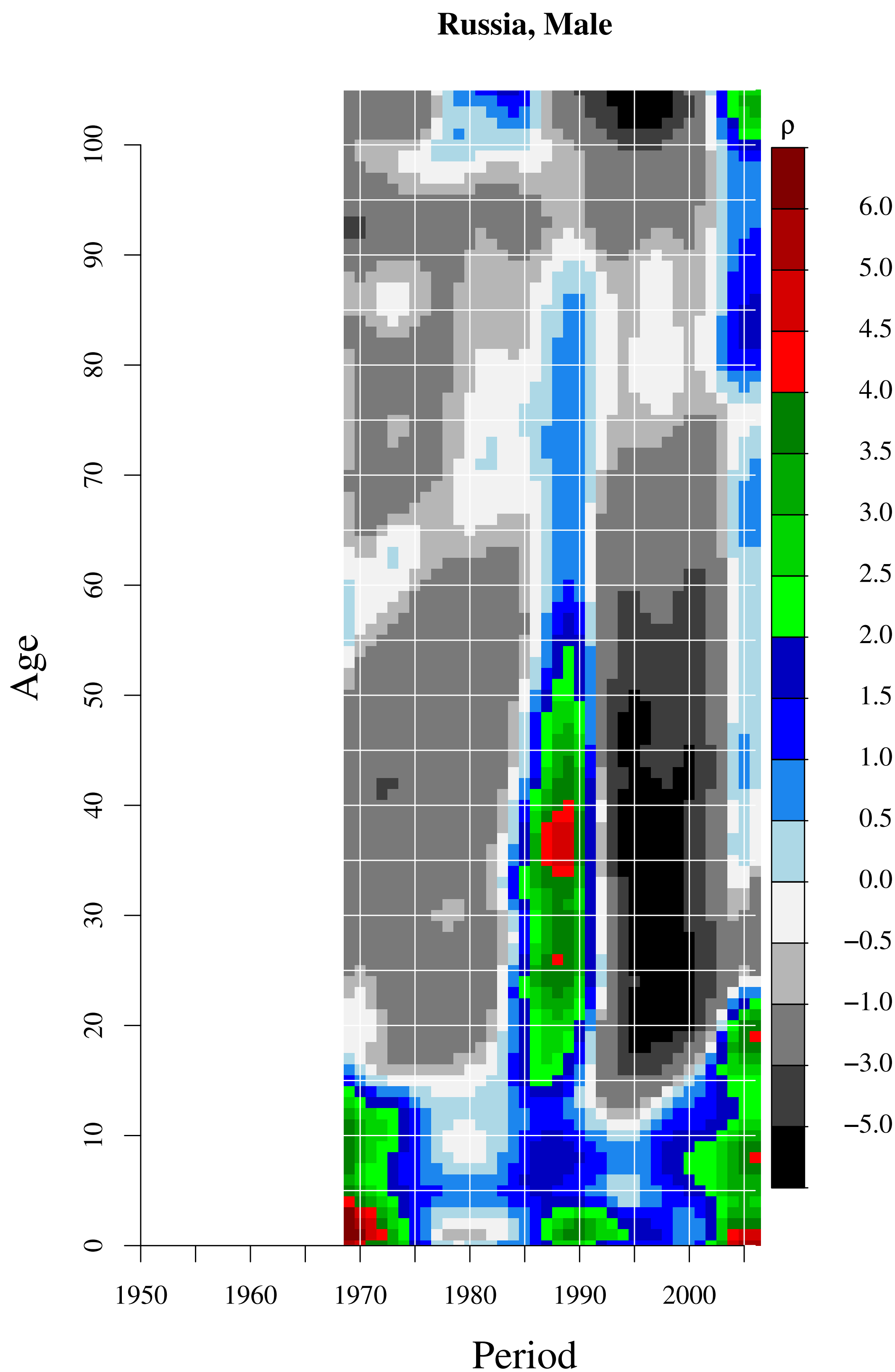


Figure 6: Average Annual Improvements in Mortality, Belarus, Males

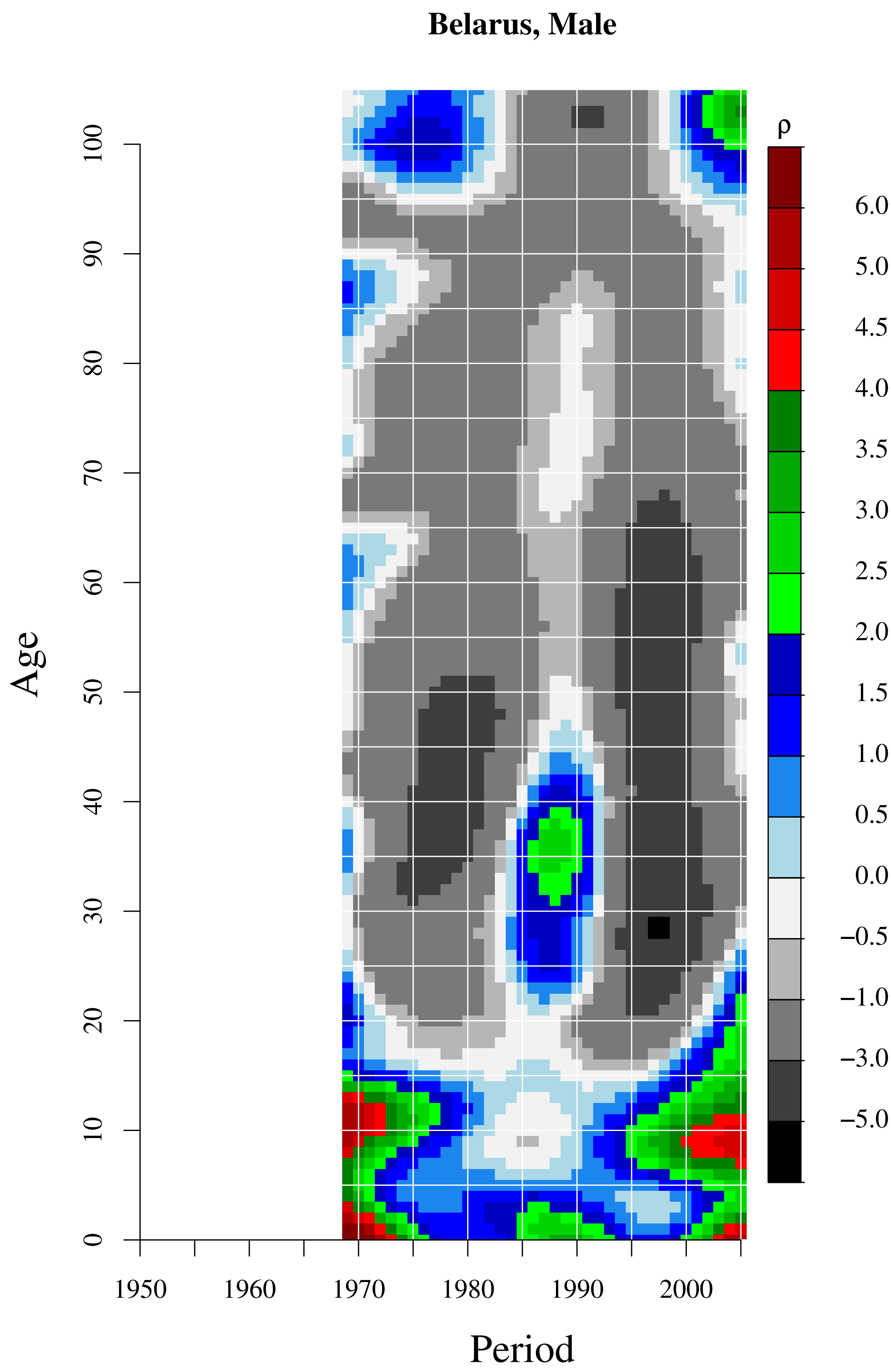


Figure 7: Average Annual Improvements in Mortality, Ukraine, Males

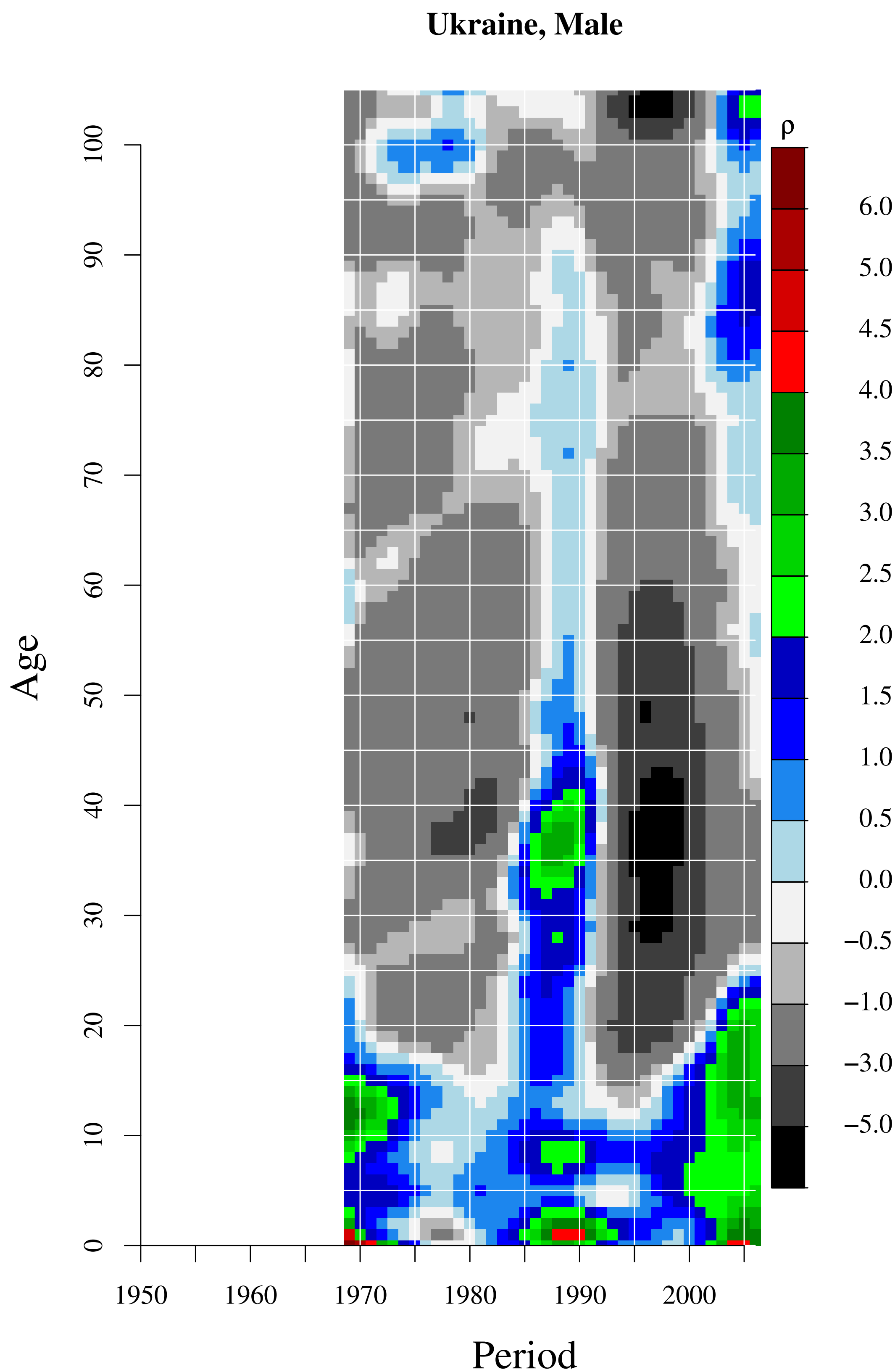


Figure 8: Average Annual Improvements in Mortality, Denmark, Females

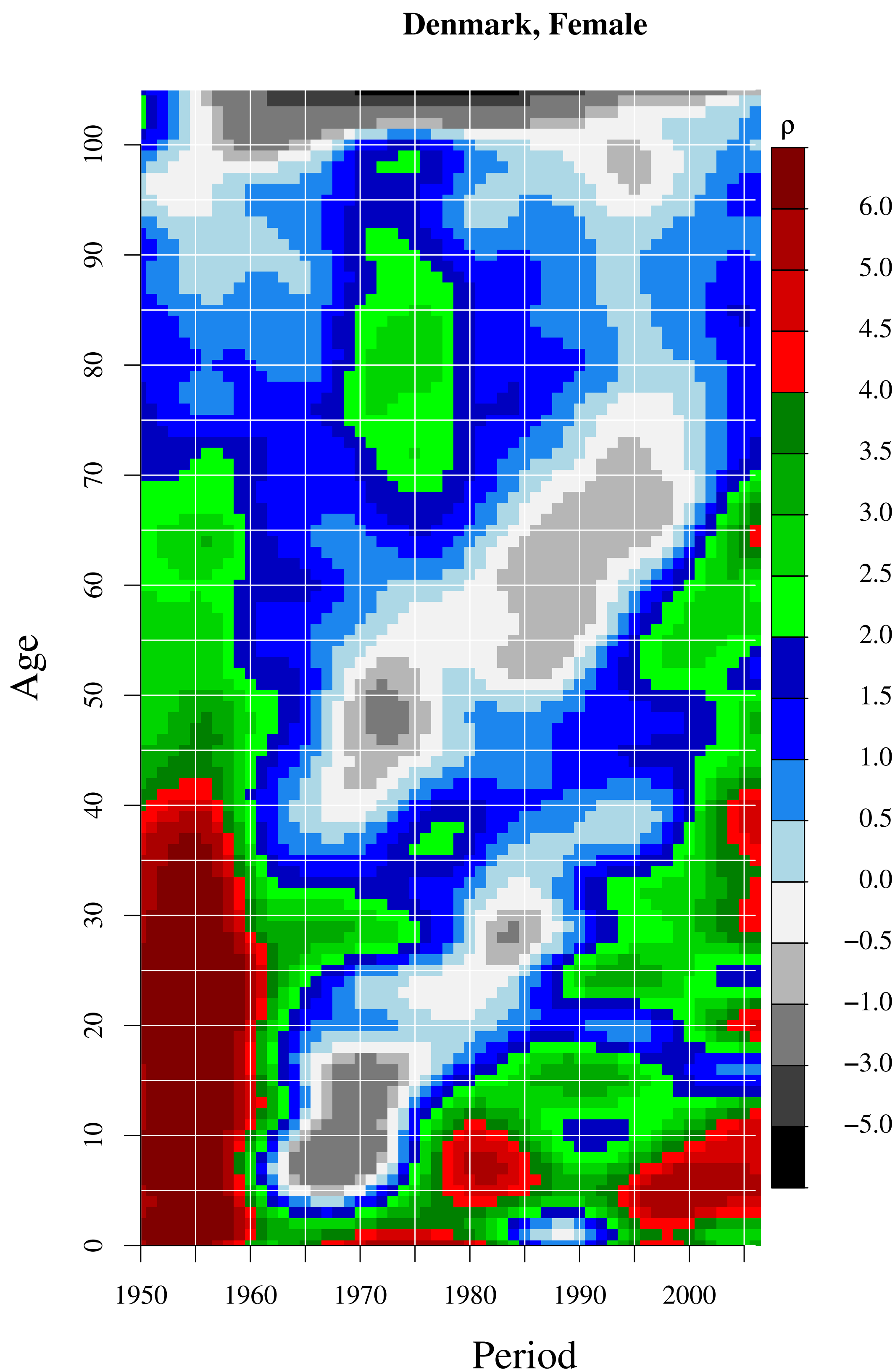


Figure 9: Average Annual Improvements in Mortality, USA, Females

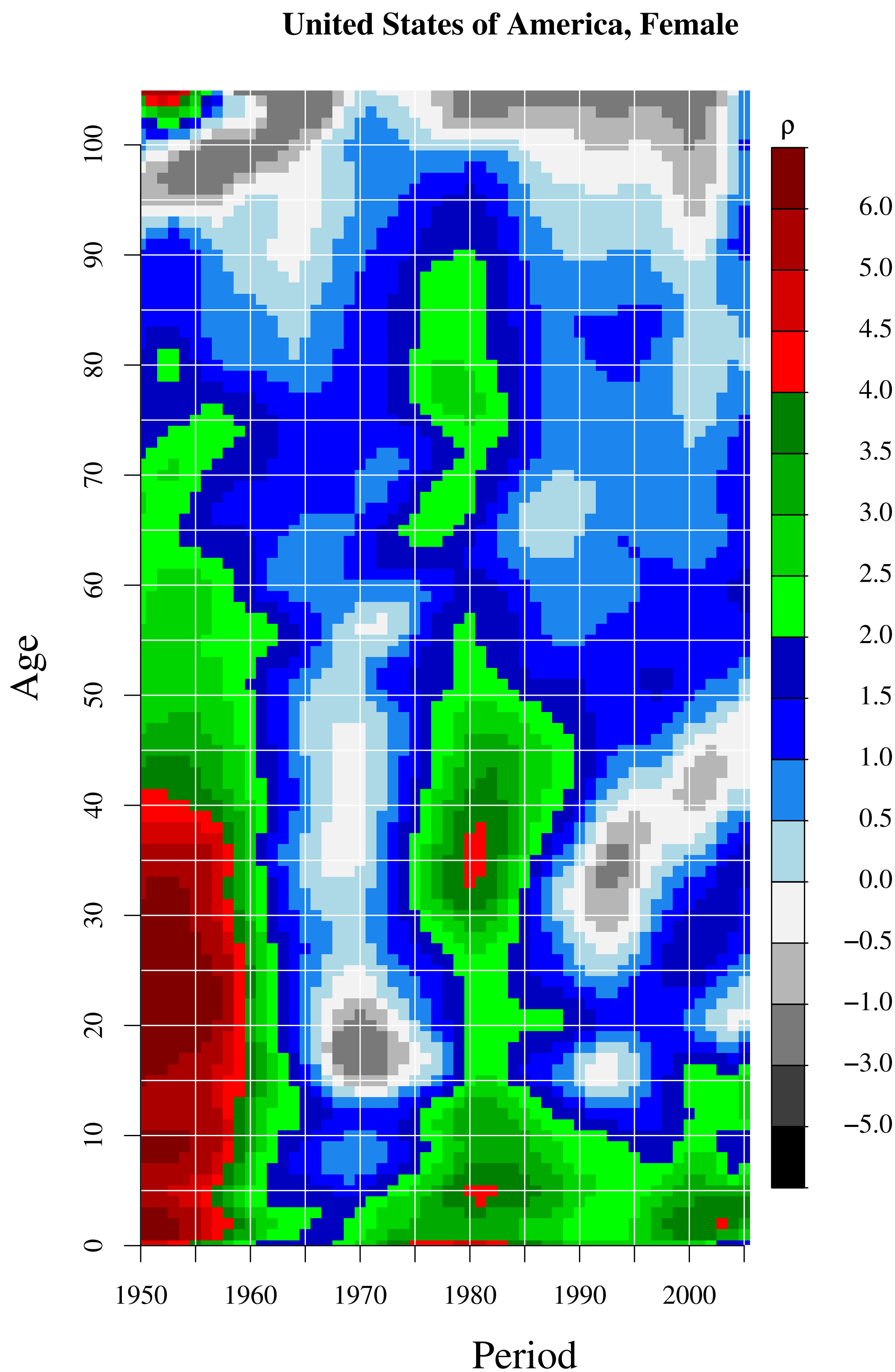


Figure 10: Average Annual Improvements in Mortality, USA, Males

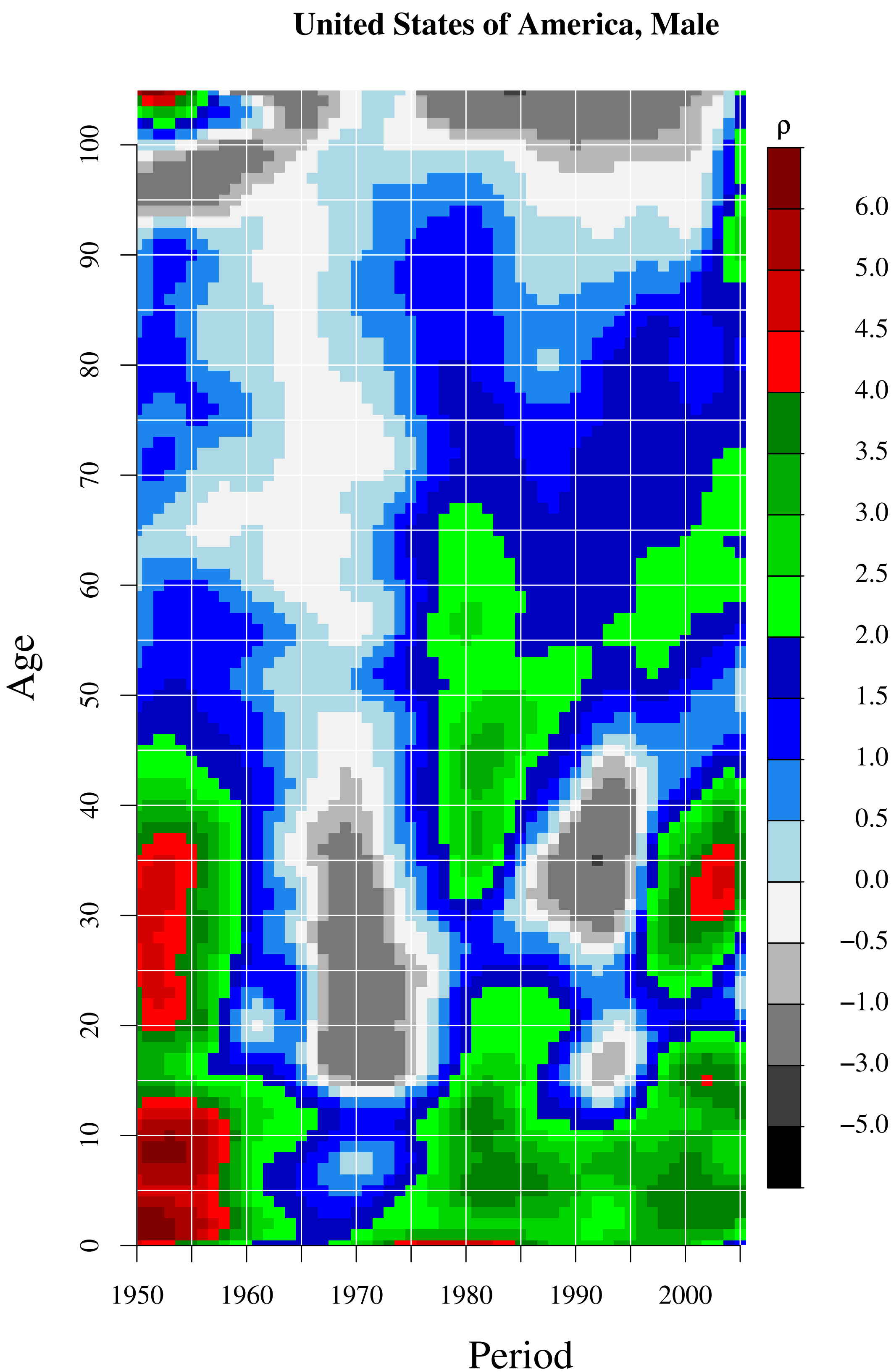


Figure 11: Average Annual Improvements in Mortality, England & Wales, Females

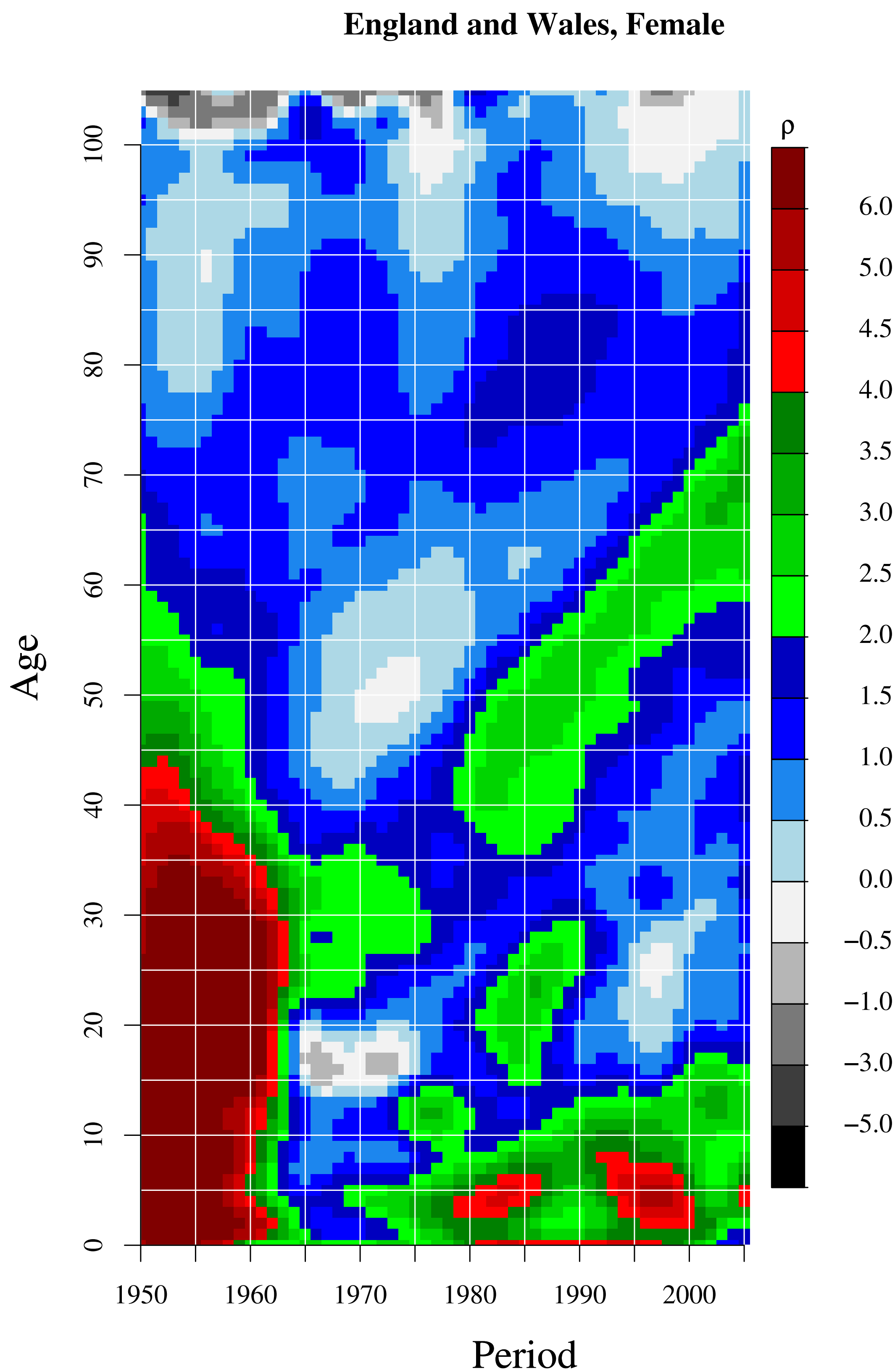


Figure 12: Average Annual Improvements in Mortality, Finland, Males

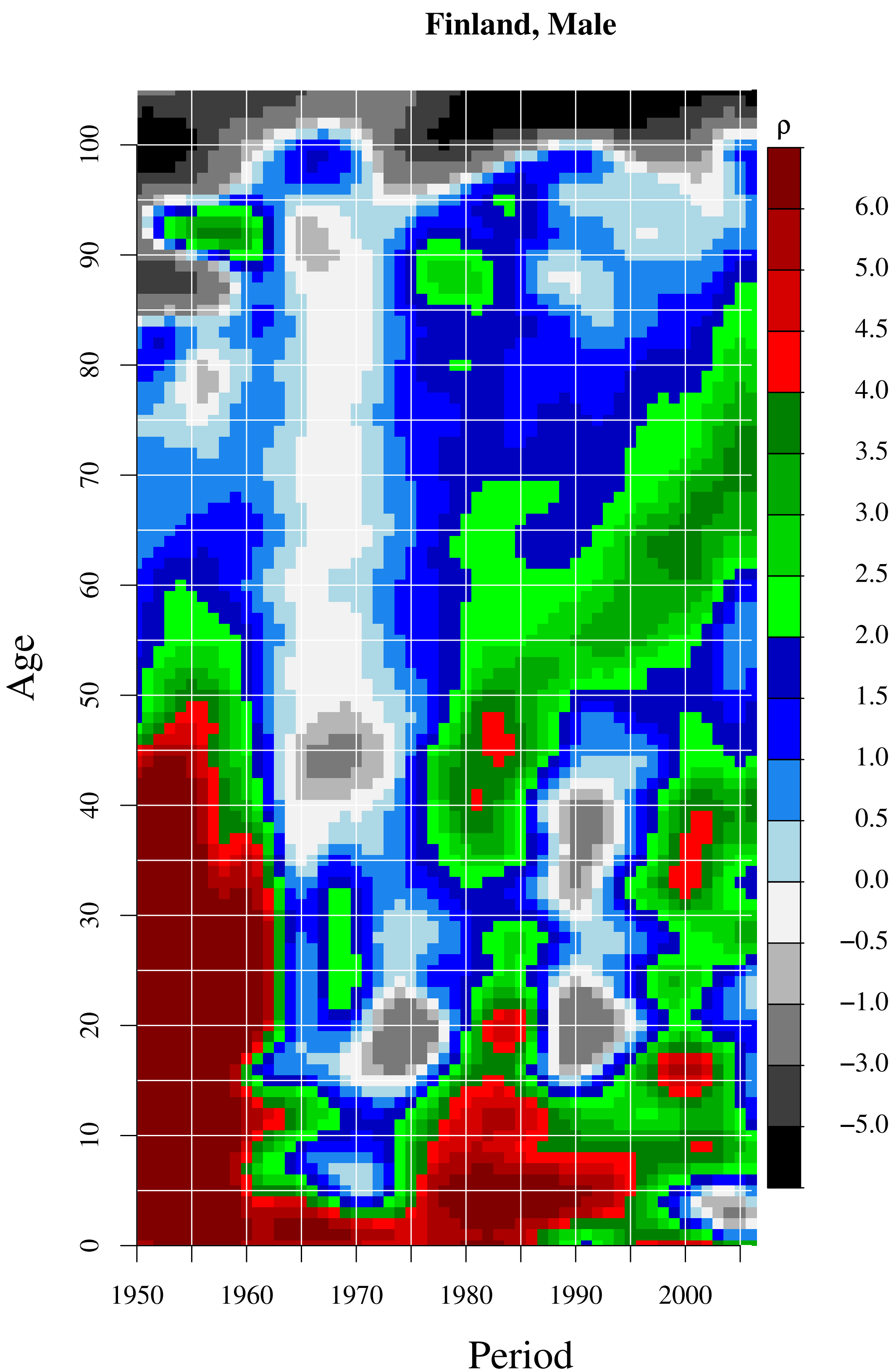


Figure 13: Average Annual Improvements in Mortality, Japan, Females