Birth Cohorts, Synthetic Cohorts, and SES Differentials in Longevity: The Implications of Changing Educational Distributions for Life Expectancy Gradients

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Abstract

One of the primary goals of social demographers is to study educational differentials in life expectancy. Findings from recent research have proposed that shifting education distributions across cohorts are influencing estimates of educational-gradients in mortality. In this study, we use high-quality Finnish register data for 1971-2010 to identify an empirical regularity in the relationship between percentile rank in the education distribution and mortality at ages 30 and older. We specify and estimate a two-parameter model that allows us to adjust for changes in the education distribution over time and use the model parameters to generate educational quintile-specific life expectancies for eight 5-year periods. These distribution-adjusted absolute education differentials in life expectancy have increased for men, but not for women between 1971 and 2010. Although relative education inequality in mortality has increased for both sexes, this effect is not observed for absolute life expectancy differentials for women, partly due to more rapid declines in overall mortality among women than men. Roughly 39% and 100% of the increase in absolute educational differentials in life expectancy for men and women, respectively, can be attributed to shifting education distributions. Had the relative inequality parameters of mortality differentials governing the Finnish population remained constant at the 1971-75 values, the absolute difference in life expectancy between the top and bottom education quintiles would have narrowed by 1.0 years for men and 0.4 years for women. A comparison of similar estimates for the United States suggests that educational expansion in the U.S. has also influenced education-mortality gradients. Estimates of the growth in the absolute life expectancy gradients are 16% and 73% larger using education categories versus distribution adjusted education quintiles for non-Hispanic white men and women, respectively.

Introduction

The measurement of inequality and its consequences is one of the primary enterprises of social demography, and accordingly much attention has been focused on whether growing social inequality is driving inequality in life expectancy and health. Life expectancy is an absolute measure of wellbeing, and absolute differentials in life expectancy have implications for non-health related outcomes such as wealth accumulation and the receipt of social security and pension income. Given the importance of social inequalities in mortality, whether measured by educational attainment, income, or occupational status and changes therein over time, it is important to consider how cohort-specific changes in the distribution of these social indicators contribute to changing period measures of inequality in mortality. The main focus of this paper is to illustrate how cohort-specific changes in educational distributions influence period estimates of disparities in mortality by educational attainment.

Many prior studies have documented educational gradients in mortality and attempted either to explain factors that contribute to their existence or document how educational disparities have changed over time (Elo, Martikainen, and Smith 2006; Elo and Preston 1996; Hendi 2015; Ho and Fenelon 2015; Mackenbach et al. 1999; Meara, Richards, and Cutler 2008; Montez and Zajacova 2013). However, recent research has raised questions about whether studying changes in educational differentials in mortality without consideration for shifting educational distributions is appropriate (Begier, Li, and Maduro 2013; Dowd and Hamoudi 2014; Hendi 2015). There are two main issues that arise when education distributions are shifting. First, over-time comparisons of the difference in mortality between education groups may be biased measures of the change in social gradients in mortality. Second, cross-sectional (within-time-period) estimates of education-specific period life tables consist of the mortality experience of multiple birth cohorts, each having a different educational distribution, such that the period estimates may not correspond to the real experience of any cohort with a given level of schooling (Bound et al. 2015; Hendi 2015). Consider, for example, the experience of cohorts that provide input for estimates for a period life table by educational attainment. Currently, individuals with the lowest level of education aged 80-84 years might be at the 45th percentile of the education distribution for their cohort, whereas people in the same education category aged 30-34 years might be only at the 5th percentile of the educational distribution for their birth cohort. In this case, the period life table for people in the lowest education category would combine younger individuals with a very low relative education and older individuals with a higher relative education. Similar difficulties emerge in the estimation of life tables for other social characteristics; in particular categorical indicators such as marital status.

Most studies of the association between education and mortality categorize educational attainment by educational milestones, such as less than high school, high school, some college, and college graduate and above or some variation of these educational categories with more or less detail. This choice may be justified by the relatively rigid demands for educational certificates for most occupations in modern societies. However, when educational attainment is improving across birth cohorts, the shift in the education distribution leads to changes in the composition of the education categories such that selection on observed and unobserved characteristics, that are also likely to be health-related, is changing over time. Thus, comparisons of mortality levels by static categories of educational attainment may lead to a misleading interpretation of changes in the education-mortality gradient over time.

Several prior studies which have addressed the issue of changing education distributions have relied on the slope index of inequality (SII), which accounts for differences in the education distribution over time or between populations (Pamuk 1985; Preston, Haines, and Pamuk 1981). It does so by plotting the percentile rank of an education category against the age-standardized death rate or life expectancy for that category, and then estimating the weighted linear association between those two variables, where the weights are equal to the relative size of the education categories (Elo and Preston 1996; Mackenbach and Kunst 1997; Moreno-Betancur et al. 2015; Valkonen 1989). In the United States, the results from analyses based on the SII typically show smaller changes in the educational gradient in mortality over time than when the changes in the education distribution are not taken into account (Preston and Elo 1995). Others have addressed the issue by not relying on educational thresholds but rather allocating individuals to equally sized rank-ordered education categories over time (Bound et al. 2015; Hendi 2015). Findings from such analyses suggest that the conclusions regarding changes in the education-mortality gradient in the United States depend on how educational attainment is classified. When changes in the educational distribution are taken into account, the changes in the education gradient are smaller than without such adjustment.

In this paper, we demonstrate how educational expansion affects measurement of inequality in mortality in Finland and the U.S., and introduce a methodological approach which allows us to measure educational gradients in period life expectancy while adjusting for changes in the education distribution across cohorts. This approach is based on the negative logarithmic relationship between education-specific mortality ratios and the education category's percentile rank in the education distribution. We use high-quality Finnish registry data to show that this logarithmic relationship holds across age and sex groups and over time. We then construct a series of curves tracing out the relationship between exact education percentile and mortality over time. We show that while relative educational differences in mortality have indeed steepened over time, much of the change over time in the absolute life expectancy difference between the highest and lowest education categories is due to the shifting education distribution. These results, coupled with our finding of a universal logarithmic relationship between mortality ratios and educational percentile, suggest that using education categories as the stratifying measure will tend to overstate the over-time widening of the social gradient in life expectancy. Our findings are similar to those of Bound et al. (2015) that demonstrate that much of the increase in the relative education-mortality gradient is due to trends at the low end of the education distribution, where fewer and fewer people are concentrated over time. Finally, we compare our Finnish results to those for the United States.

The Historical Context of the Finnish Educational Transition

Although today Finland is considered one of the most forward-thinking countries in terms of education, for much of the twentieth century, it was a largely agrarian society with low levels of formal education. Most people born before the 1920s had at most four years of formal schooling. The first major change in the Finnish education system occurred in 1921 with the Compulsory Education Act of 1921. This law guaranteed six years of formal education to all Finnish citizens and it was very rapidly adopted and implemented. As a result, there was quite a stark educational divide between cohorts born prior to this period and those born afterwards.

To achieve the dual goals of promoting social equity and economic growth the government implemented a new schooling reform: the 1968 Basic Education Reform Act. The 1968 Act made 9 years of schooling compulsory for all Finnish children. It was thought that this measure would level class differences in educational opportunities and also prepare Finland to enter into the global economy in the expanded manufacturing and service industries. This education reform coincided with rapid industrialization and growth of the service sector in the 1950s and 1960s and mass rural-to-urban migration in the 1960s and 1970s. It was fully implemented by 1977. The educational expansion prepared a greater number of Finns to participate in the service industry.

Following the 1970s, education reform took on its own momentum, leading to ever-higher levels of educational attainment for the younger segment of the Finnish population. Education grew in importance not only as a means to produce economic growth but also as an end in its own right—a social right. Smaller reforms in the 1980s, 1990s, and 2000s allowed for greater flexibility in transitioning between vocational and academic educational tracks in a further attempt to level class differences (Aho, Pitkanen, and Sahlberg 2006). Secondary and tertiary education expanded significantly in the post-war period.

Cohort Effects, Status, and Education

One of the defining features of the Finnish education transition is that the major changes were implemented very rapidly—often within a period of five years—and thus produced large differences in educational attainment between earlier and later cohorts. This transformation can be seen mostly clearly in Figures 1 and 2, where we can see a decline in the proportion of people with only a basic education corresponding to cohorts who completed their schooling after the 1920s as a result of increasing number of people obtaining secondary and tertiary schooling. Similarly, cohorts that completed schooling prior to the 1970s have a very different education profile than cohorts that benefited from the education reforms of 1968. Because most formal schooling is completed by age 30, we can say that education transitions imprint distinctly on cohorts. Birth cohorts separated by only a decade may have very different education profiles.

Why does the status attached to a given educational level differ across birth cohorts?

The educational reforms that were undertaken led to a credentialing process for entry into different segments of the labor market. The same type of job that one could have had previously now required a higher level of schooling. This patterning is reflected in Figure 3, which plots the education distribution within occupational categories for men (lower occupation category numbers indicate higher social class). It's apparent that within the same occupation types, the education distribution shifted across cohorts. Ivar Berg and Randall Collins theorized about this process in the sociology of education and the labor market literature and Michael Spence in the economics literature. All three authors predicted that because of increased labor market competition, individuals will compete on the basis of status to signal their value to potential employers. Employers in turn hire those with the best signal, which is equivalent in this context to higher level of education (Berg 1970; Collins 1971, 1979; Spence 1973).

Within the Finnish context, competition for jobs was not based on education in the early 20th century. It was based largely on families' social class, which was determined by a variety of other factors including place of residence, families' occupational history, and wealth. This pattern began to change in the 1920s and accelerated during the postwar era. In the postwar era, the incentives to compete on education increased both domestically and internationally. At the international level, Finland increased her participation in the global economy and accepted global norms, including the belief that people should complete secondary or even tertiary education. There is evidence that the leaders of Finland kept a close eye on foreign academic literatures, which posited that human capital formation was one of the best ways to promote economic growth (Aho et al. 2006). At the domestic level, the loss of land to the USSR along with the decline in farming led to competition for jobs in the industrial and service sectors. People needed to compete for jobs, and they began to do so on the basis of education.

In summary, earlier in the twentieth century, education was only loosely tied to status, and did not figure strongly in competition for jobs. Policies implemented in the 1970s led the entire Finnish population to rapidly increase its mean level of education. By the 1980s, education had become much more important for jobs and thus became a strong marker of socioeconomic status. This intensification of status competition was reinforced by the acceptance of world society norms including the desirability of higher education, and globalization, which forced the Finnish population to compete more directly with people in other countries.

The increased status competition in the labor market led to greater status differentiation by education level for later birth cohorts than for earlier birth cohorts. Essentially, education was a better determinant of socioeconomic status for people born later.

Over the same time period—the 1960s through the present era—Finland experienced growing educational differentials in life expectancy. While prior to the 1960s, mortality differentiation might have been determined mostly on the basis of social class or urban-rural status, education became a better predictor of mortality relative to the past. This suggests that part of the growth in the educational gradient in mortality may be due to the fact that education became more closely tied to status, which has always been a prime determinant of mortality. Thus, when attempting to measure socioeconomic gradients in mortality, one must take care to ensure that the measurement uses an indicator of socioeconomic status that is consistent across birth cohorts. For all its virtues, education is not a consistent measure of status across cohorts. In this article, we present a parameterization of the relationship between the education distribution and mortality that allows us to generate estimates of status gradients in mortality based on educational attainment that are more consistent across cohorts.

Data and Methods

We use data on deaths and exact person-days lived cross-tabulated by sex, age, and education for Finland in the following five-year periods: 1971-1975, 1976-1980, 1981-1985, 1986-1990, 1991-1995, 1996-2000, 2001-2005, 2006-2010. The data come from five-year censuses and death register data and are provided by Statistics Finland. Age is collapsed into five-year age groups and education is categorized into a 6-category measure: elementary school or no formal schooling (henceforth basic), middle school, high school, vocational degree, polytechnic college degree, and university degree or higher. For the 2001-2005 period and later, the education categorization changes slightly and collapses the second group with a portion of the third group (the categorization for the lowest and the highest education groups remains the same). The person-years measure is the total number of days lived by people within a sex-age-education group in a given five-year period. Individuals are allowed to age out of and into adjacent age groups. Mortality follow-up (the counting of person-days) begins as of January 1 of the first year within the five-year period, and education is measured at the time of the census.

Death Rates and Life Tables

We compute age-sex-education-specific mortality rates (occurrence-exposure ratios) by five-year age groups for each of the seven time periods listed above, for age groups 30-34, …, 90-94, 95+ years. We do not compute death rates for people aged younger than 30 since many of them are unlikely to have completed their education by that age. Ages 95 years and older are combined into an open-ended age group and the death rate is presumed to be constant. Each rate is multiplied by 365.25 so that the rates are measured in terms of deaths per person-year. Abridged life tables starting at age 30 years are computed using standard methods with ${}_na_x$ calculated by using Keyfitz's iteration approach (Preston, Heuveline, and Guillot 2001) (iterations continued until all age-specific ${}_na_x$ values in the life table changed by less than 0.0001 from one iteration to the next).

Modeling the Relationship between SES and Mortality

Since our objective is to examine the relationship between education percentile (that is, position in the education distribution) and mortality, we computed age-sex-period-specific education distributions and mortality ratios. Within an age-sex group in a given five-year period, we divided each of the seven education-specific death rates by the general mortality rate (the age-sex-specific mortality rate for that period). This produced six mortality ratios for each age-sex group in each period (with the exception of the 2001-2005 and 2006-2010 periods, which had only five education categories):

$$R_i = {}_nm_x^i / {}_nm_x \quad i = 1, \dots, 6$$

where ${}_nm_x^i$ is the death rate for education group i, and ${}_nm_x$ is the death rate for the general population. We then computed the education distribution for each age-sex group in each period by tabulating the number of person-years lived by each education group and dividing by the total person-years lived across all education groups within the age-sex group in that period. The education percentile for each age-sex-education group in a given year is the percentile corresponding to the halfway point for the education group within the education distribution in that period. For example, in 1971-1975 the middle school education group for males aged 30-34 ranged from the 56th percentile to the 77th percentile. The midway point for this group is (0.56+0.77)/2 = 0.67, so the education percentile value for 30-34 year-old males in 1971-1975 with a middle school education is 0.67. By 1996-2000, the middle school education group for males aged 30-34 ranged from the 20th percentile to the 55th percentile. The midway point for this group is (0.20+0.55)/2 = 0.38, so the education percentile value for 30-34-year-old males in 1996-2000 with a middle school education is 0.38. We then plotted the mortality ratios against the education percentile values to trace out the socioeconomic gradient in mortality.

Based on the observed relationship between the mortality ratios and the education percentile, we estimated regressions of the following form:

$$\log(R_i) = \alpha + \beta e_i + u_i \qquad i = 1, \ldots, 6$$

where i represents an education group, R_i is the education-specific mortality ratio for a given age-sex group in a particular period, e_i is the education percentile corresponding to education group i in that year and for that age-sex group, and u_i is a mean-zero error term. Since there are 14 age groups, 2 sexes, and 8 five-year periods, we compute a total of $14 \times 2 \times 8 = 224$ regressions, each with two parameters (α and β). The α and β parameters are the skewness and inequality parameters, respectively, pertaining to the education-mortality relationship. e^{α} can be interpreted as the mortality ratio relative to the general population for people at the bottom of the education distribution. All else being equal, a higher α value indicates that mortality is more concentrated (skewed) toward the lower end of the education spectrum. If α increases over time, then there is evidence that the mortality of the most poorly educated is diverging from the general level of mortality in the total population. If α decreases over time, then the mortality of the most poorly educated is converging to the general level of mortality in the total population—the mortality distribution is less skewed towards lower levels of education. The β parameter indicates the overall level of relative mortality inequality by educational attainment. $(e^{\beta} - 1)$ can be interpreted as the average percent difference in mortality between the 0th and 100th percentiles of the education distribution. For example, a β value of -1.8 means that individuals with the highest level of education have mortality rates that are around 83% lower than individuals with the lowest level of schooling ($e^{-1.8} - 1 \approx -0.83$). If β decreases over time, then there is evidence that the relative difference in mortality between individuals with the highest and lowest level of schooling is growing. A mean-preserving change in α requires that β changes in the opposite direction. In other words, if the situation of the worst-off is improving relative to the total population (α is decreasing) but the total mortality rate in the population remains constant, then by necessity the best-off must shoulder a greater portion of the mortality burden (β must increase). Together, these two parameters summarize the main features of the educational gradient in mortality: the relative difference between the lowest-education and the highest-education, and the portion of the education spectrum where inequality is concentrated.

Computing Life Tables by Educational Quintile

The major objective of this analysis is to compute life tables that take into account the changing education distribution across birth cohorts in a given time period and across time. To do so, we must be able to compare a fixed set of education categories—for example, quintiles of educational attainment and compute life tables based on the mortality rates corresponding to those fixed quintiles. We can use the regression estimates (α and β) to compute mortality rates that correspond to the education quintiles. If an education quintile ranges between education percentiles a and b, then the average mortality ratio corresponding to that quintile is:

$$\bar{R}_{(a,b)} = \frac{1}{b-a}\int_a^b e^{\alpha+\beta x}\,dx = \frac{e^{\alpha}}{\beta(b-a)}\left(e^{\beta b} - e^{\beta a}\right)$$

which means that the average mortality rate corresponding to that quintile is just the age-sex-specific general mortality rate multiplied by $\bar{R}_{(a,b)}$. For example, if the second education quintile ranges from 0.20 to 0.40, then $b = 0.40$ and $a = 0.20$. If, for a given age-sex group in a particular period, $\alpha = 0.8$ and $\beta = -1.8$ then $\bar{R}_{(a,b)} = 1.3$. For example, males aged 30-34 in 1986-1990 had a death rate of 0.002, so if their α and β parameters were 0.8 and -1.8, respectively, then their second-quintile-specific death rate is $1.3 \times 0.002 = 0.0026$.

Using the two model estimates we compute quintile-specific death rates for each age-sex group in each of the eight periods to produce a full set of age-specific death rates for 80 distinct life tables (5 quintiles over 8 periods for 2 sexes).[1] We then compute the life tables, again using Keyfitz's iteration technique to calculate the ${}_na_x$ values.

Counterfactuals

Finally, we also compute counterfactual estimates. These counterfactual estimates allow us to make statements like: "If relative educational inequalities in mortality hadn't changed over time (but if general mortality rates evolved as observed), what would be the difference in life expectancy between the first and fifth quintile of the education distribution?" To do so, we can simply borrow the α and β estimates from 1971-1975 and apply them to the 1976-1980, 1981-1985, 1986-1990, 1991-1995, 1996-2000, 2001-2005, and 2006-2010 general mortality rates to compute the counterfactual life table.

Results

As discussed previously and shown in Figures 1 and 2, there were large changes in the education distribution among both male and female birth cohorts in Finland over time.

Table 1 shows life expectancy at age 30 by education for each of the seven time periods for men and women separately. Life expectancy increased for all education categories, though

[1] Note that these quintiles do not correspond directly to the education categories. We use the education categories to estimate the education-mortality relationship and then use the estimated relationship to produce quintile-specific mortality rates.

not at an equal pace. People with higher levels of education tended to experience faster increases in life expectancy than people with lower levels. This led to an increase in the difference in life expectancy between university degree holders and people with basic education. Between 1971-1975 and 2006-2010, this differential increased from 5.1 years to 8.3 years for men (a 3.3 year increase) and from 3.6 years to 4.6 years for women (a 1.0 year increase). This increase in the life expectancy differential is entirely due to faster increases among the most educated.

Figure 3 shows the distribution of education within occupation categories over time. Within a given occupation category, the education distribution shifted rightward across periods. In other words, the educational qualifications required for the same types of jobs became higher for later birth cohorts. Thus, individuals who obtained higher status occupations in earlier periods needed less schooling than individuals in later birth cohorts.

Figures 4 and 5 plot the relationship between the education percentile and mortality ratios (the ratio of education-specific mortality to general mortality). The point markers represent the year and 5-year age groups, the colors highlight the first (red) and last (blue) year of observation. We find a strikingly regular negative logarithmic relationship. Mortality ratios are highest for people with the lowest level of schooling, and lowest for those with highest level of education. The points cross the 1.0 (equality) line at around the 50th percentile of education for men and the 40th percentile for women, indicating a slightly greater concentration of inequality at the lower SES levels for men than for women. The negative logarithmic relationship appears to hold for both men and women and for all age groups and time periods, though the relationship is clearer for people aged 30-84. This is consistent with the lack of a large educational gradient in mortality among people aged 85+.

Figures 6 and 7 plot the percent difference in mortality between the least and most educated people for males and females, respectively. Each line represents a different 5-year age group. These estimates are computed as $e^{\beta} - 1$, where β comes from the logarithmic regression estimates (described in the Methods section) that model the relationship between education index and mortality ratios. As expected, the percent differences are greatest for people at younger ages, where mortality gradients are more pronounced and where overall mortality rates are lower, and smallest at older ages, where mortality gradients tend to be muted and where overall mortality rates are higher. We see that for both men and women, the percent difference increased over time in magnitude (that is, they became more negative). The changes were most pronounced for younger age groups.

Figures 8 and 9 plot the concentration of mortality inequality among the least educated for males and females, respectively. Each line corresponds to a single five-year age group. The values are computed as e^{α} (the mortality ratio for people at the 0^{th} percentile of the education distribution), where α comes from the regression equations described above. While α is a level parameter in the regression, because the outcome is a relative measure, α actually describes the concentration of mortality at the low end of the education spectrum. The lines tend to be higher for males than for females. The clearest pattern from these graphs is that younger age groups have a greater portion of inequality concentrated at the low end of the education spectrum. For males aged 30-34, the values range from nearly 2.0 to well above 2.5. For males aged 85-89, however, the values are much closer to 1.0. This is consistent with, but not entirely explained by, the leveling of socioeconomic gradients in mortality at the older ages. The second noticeable pattern is that the concentration of inequality at lower levels of education has trended upward over time. In other words, as time progresses, the reason for rising educational inequality in mortality is increasingly concentrated at the low levels of schooling.

Table 2 shows life expectancy at age 30 by education quintile. These values are computed using the general (not by education) age-specific mortality rates and the regression estimates described earlier. Life expectancy increased for all education quintiles for both men and women. For men, life expectancy increased more quickly for those in the higher education quintiles than for those in the lower quintiles. This is not the case for women. Women in all five education quintiles experienced increases in life expectancy between 6.6 and 6.8 years. The difference in life expectancy between the fifth and first education quintiles increased from 6.3 years to 8.3 years (2.0-year increase) between 1971-1975 and 2006-2010 for men. The difference in life expectancy between the fifth and first education quintiles did not change for women between 1971-1975 and 2006-20105. However, women did experience a slight decrease in the difference between 1971-1975 and 1986-1990, and then a slight increase from 1996-2000 to 2001-2005.

Table 3 shows counterfactual life expectancies at age 30 by education quintile. The counterfactual scenario fixes the α and β parameters to their 1971-1975 levels and allows general mortality rates to improve as observed. This table, coupled with the results in Table 2, answers the question: "How much of the widening in the educational gradient in life expectancy is due to changes in the inequality parameters in Finland (net of secular mortality declines and changing educational composition)?" We find that if such a scenario held, then the individuals with lowest level of education would experience greater increases in life expectancy than those with the highest level of schooling. For men, life expectancy among the first quintile would increase from 36.1 to 44.6 years (8.5-year increase), where life expectancy among the fifth quintile would increase from 42.4 to 49.8 years (7.4-year increase). This would shrink the difference in life expectancy between the first and fifth quintiles by 1.0 and 0.4 years for men and women, respectively. Since total (non-education-specific) mortality rates were allowed to vary as observed in the actual population, total life expectancy in the counterfactual scenario is equal to total life expectancy in the factual scenario. When coupled with Table 2, these results suggest that, net of secular declines in mortality, the growth in inequality is responsible for a widening of the life expectancy gradient on the order of 3.0 years for men ($2.0 - (-1.0) = 3.0$) and 0.4 years for women ($0.0 - (-0.4)$ = 0.4).

Comparison to the United States

We applied the same methods as above to data for non-Hispanic whites from the U.S. National Longitudinal Mortality Study (NLMS) for the 1980s, 1990s, and 2000s to calculate changes in life expectancy by educational attainment in the United States. The results shown in Tables 4-6 are broadly similar to those we documented in Finland. Life expectancy differentials across education categories were typically larger than differentials between the top and bottom education quintiles. As with the Finnish data, we find that educational expansion had more of an effect on mortality inequality for women than for men. For white women, the growth in the quintile gradient was 3.0 years, which is 2.2 years less than the 5.2-year growth in the education category differential. For white men, the growth in the quintile differential was 3.1 years, which was 0.5 years less than the growth in the 3.6-year growth in the educational category differential. This suggests that for non-Hispanic whites, educational expansion may have had larger effects for women than for men for this set of birth cohorts in the 1980s-2000s. This seems sensible, since white women had a more recent and rapid educational transition than did white men, as reflected in Figures 10-11, which plot changes in the educational distribution for white men and women, respectively, between the 1980s and 2000s.

Discussion and Conclusion

The great majority of contemporary research on socioeconomic gradients in mortality has studied the association between education and mortality using fixed educational thresholds, and most researchers have had some difficulty in dealing analytically with accounting for shifting education distributions (Ho and Fenelon 2015; Miech et al. 2011; Montez and Zajacova 2013, 2014).

The first empirical contribution of this study is to identify what appears to be an empirical regularity in the relationship between educational attainment and mortality. We find that there is a negative logarithmic relationship between the percentile rank of an individual's education and the ratio of that percentile's mortality to the total mortality rate in Finland and the United States(?). We say this relationship is regular because it appears to hold across both sexes, all relevant age groups, and across time. The discovery of this empirical regularity allows us to make our second empirical contribution.

The second contribution is to develop a method which adjusts for cohort differences in the education distribution when computing differentials in life expectancy using period life tables. This method uses the fact that there is a negative logarithmic relationship between educational attainment and relative mortality to estimate a two-parameter model, which traces out a relationship between the education percentile and mortality. This allows us to construct period life tables corresponding to any arbitrary segment of the education distribution. It also enables us to compute education gradients adjusting for the fact that the education distribution has been changing over time and across cohorts. This method has further applications in terms of making comparisons across populations (e.g., international comparisons or comparisons across states), since different populations have differing education distributions.

We apply this new methodology to data from Finland and the United States to compute education quintile-specific life tables in multiple time periods. We find that much of the increase in inequality in life expectancy over time observed when using education categories to compute life expectancies can be explained by the fact that the education distribution has shifted over time in both countries. Roughly 39% of the increase in absolute inequality for men and 100% of the increase in absolute inequality for women in Finland can be attributed to shifting education distributions[2] (even though the inequality parameters increased, women's mortality declined quickly enough to cancel out this increase). In the United States, we similarly find that about 14% of the increase in the absolute inequality in life expectancy for men and 42% of the increase in absolute inequality for women can be attributed to shifting education distributions. These results suggest that future studies of educational inequalities in mortality should adjust for changing education distributions across birth cohorts when measuring educational gradients in mortality. We should also note that the issue of changing education distributions is not specific to mortality, but also should be taken into account when studying other outcomes, such as fertility and marriage.

All of this is not to say that inequality has not increased —it has. The two parameters of the regression model estimated in this paper measure the skewness and level of inequality in mortality. Both of these measures have grown more extreme over time in Finland and the United States, suggesting that had inequality not become a stronger force, then inequality in life expectancy might not have grown and might even have shrunk over time. We show through a

[2] These numbers are computed using the difference in the change in the gradient over time using categories versus quintiles: $((3.3-2.0)/3.3) = 39\%$ and $((1.0-0.0)/1.0) = 100\%$.

counterfactual exercise that had the inequality parameters of the population stayed fixed at their 1971-1975 levels, then the difference in life expectancy between the top and bottom educational quintiles for both men and women would have shrunk over time in both countries. Differences in life expectancy would have decreased because overall declines in mortality would have been more equitably shared by people across the education spectrum.

References

Aho, Erkki, Kari Pitkanen, and Pasi Sahlberg. 2006. *Policy Development and Reform Principles of Basic and Secondary Education in Finland Since 1968*. Washington, D.C.: The World Bank.

Begier, Beth, Wenhui Li, and Gil Maduro. 2013. "Life Expectancy Among Non-High School Graduates." *Health Affairs* 32(4):822.

Berg, Ivar E. 1970. *Education and Jobs: The Great Training Robbery*. New York: Praeger.

Collins, Randall. 1971. "Functional and Conflict Theories of Educational Stratification." *American Sociological Review* 36(6):1002–19.

Collins, Randall. 1979. *The Credential Society: An Historical Sociology of Education and Stratification*. New York: Academic Press.

Dowd, Jennifer B. and Amar Hamoudi. 2014. "Is Life Expectancy Really Falling for Groups of Low Socio-Economic Status? Lagged Selection Bias and Artefactual Trends in Mortality." *International Journal of Epidemiology* 43(4):983–88.

Elo, Irma T., Pekka Martikainen, and Kirsten P. Smith. 2006. "Socioeconomic Differentials in Mortality in Finland and the United States: The Role of Education and Income." *European Journal of Population* 22(2):179–203.

Elo, Irma T. and Samuel H. Preston. 1996. "Educational Differentials in Mortality: United States, 1979–1985." *Social science & medicine*. Retrieved May 15, 2013 (http://www.sciencedirect.com/science/article/pii/0277953695000623).

Hendi, Arun S. 2015. "Trends in U.S. Life Expectancy Gradients: The Role of Changing Educational Composition." *International Journal of Epidemiology* 44(3):946–55. Retrieved (http://ije.oxfordjournals.org/content/early/2015/05/03/ije.dyv062.abstract).

Ho, Jessica Y. and Andrew Fenelon. 2015. "The Contribution of Smoking to Educational Gradients in U.S. Life Expectancy." *Journal of Health and Social Behavior* 56(3):307–22.

Mackenbach, J. P. et al. 1999. "Socioeconomic Inequalities in Mortality among Women and among Men: An International Study." *American Journal of Public Health* 89(12):1800–1806.

Mackenbach, Johan P. and Anton E. Kunst. 1997. "Measuring the Magnitude of Socio-Economic Inequalities in Health: An Overview of Available Measures Illustrated with Two Examples from Europe." *Social Science and Medicine* 44(6):757–71.

Meara, Ellen R., Seth Richards, and David M. Cutler. 2008. "The Gap Gets Bigger: Changes in Mortality and Life Expectancy, by Education, 1981-2000." *Health Affairs* 27(2):350–60. Retrieved March 1, 2013 (http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2366041&tool=pmcentrez&rendertype=abstract).

Miech, R., F. Pampel, J. Kim, and R. G. Rogers. 2011. "The Enduring Association between Education and Mortality: The Role of Widening and Narrowing Disparities." *American Sociological Review* 76(6):913–34. Retrieved May 15, 2013 (http://asr.sagepub.com/cgi/doi/10.1177/0003122411411276).

Montez, Jennifer Karas and Anna Zajacova. 2013. "Explaining the Widening Education Gap in Mortality among U.S. White Women." *Journal of Health and Social Behavior* 54(2):165–81.

Montez, Jennifer Karas and Anna Zajacova. 2014. "Why Is Life Expectancy Declining Among Women in the United States ?" *American Journal of Public Health* 104(10):e5–7.

Moreno-Betancur, Margarita, Aurélien Latouche, Gwenn Menvielle, Anton E. Kunst, and

Grégoire Rey. 2015. "Relative Index of Inequality and Slope Index of Inequality: A Structured Regression Framework for Estimation." *Epidemiology* 26(4):518–27. Retrieved (http://journals.lww.com/epidem/Fulltext/2015/07000/Relative_Index_of_Inequality_and_Slope_Index_of.12.aspx).

Pamuk, Elsie R. 1985. "Social Class Inequality in Mortality From 1921 to 1972 in England and Wales." *Population Studies* 39(1):17–31.

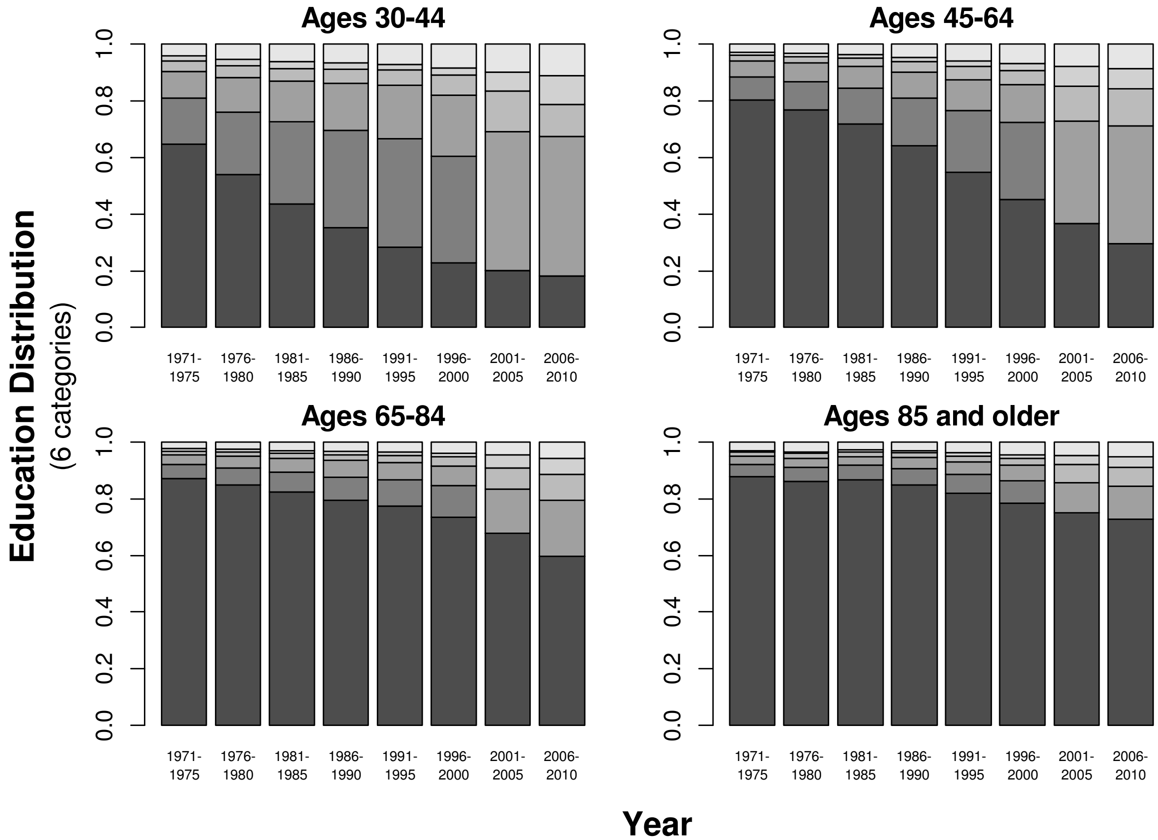
Preston, Samuel H., Michael R. Haines, and Elsie Pamuk. 1981. "Effects of Industrialization and Urbanization on Mortality in Developed Countries." Pp. 233–54 in *International Population Conference, Manila, 1981: Solicited Papers, vol. 2*. Liege: IUSSP.

Preston, Samuel H., Patrick Heuveline, and Michel Guillot. 2001. *Demography: Measuring and Modeling Population Processes*. Malder, MA: Blackwell.

Spence, Michael. 1973. "Job Market Signaling." *The Quarterly Journal of Economics* 87(3):355–74. Retrieved (http://www.jstor.org/stable/1882010).

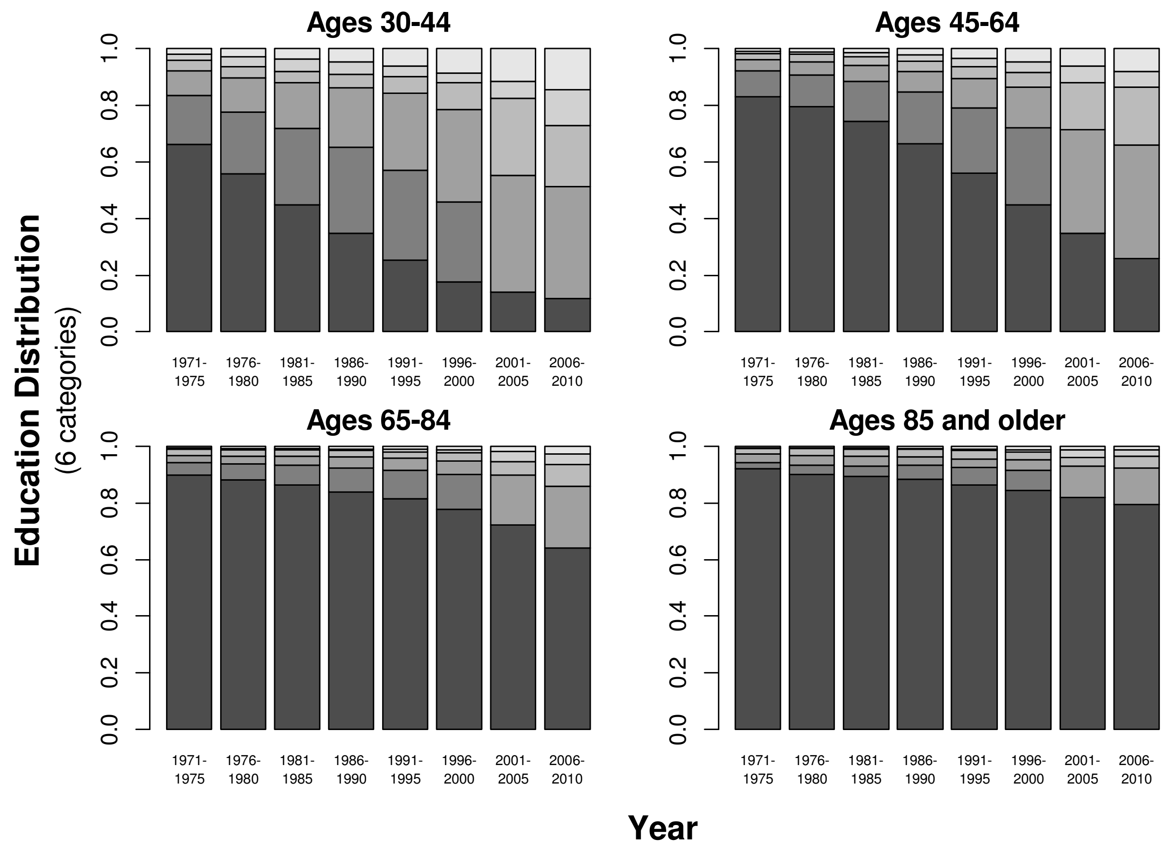
Valkonen, Tapani. 1989. "Adult Mortality and Level of Education: A Comparison of Six Countries." Pp. 144–62 in *Health Inequalities in European Countries*, edited by J. Fox. Aldershot, England: Gower.

Figure 1. Changing Education Distribution by Age and Year, Males, Finland 1971-2010



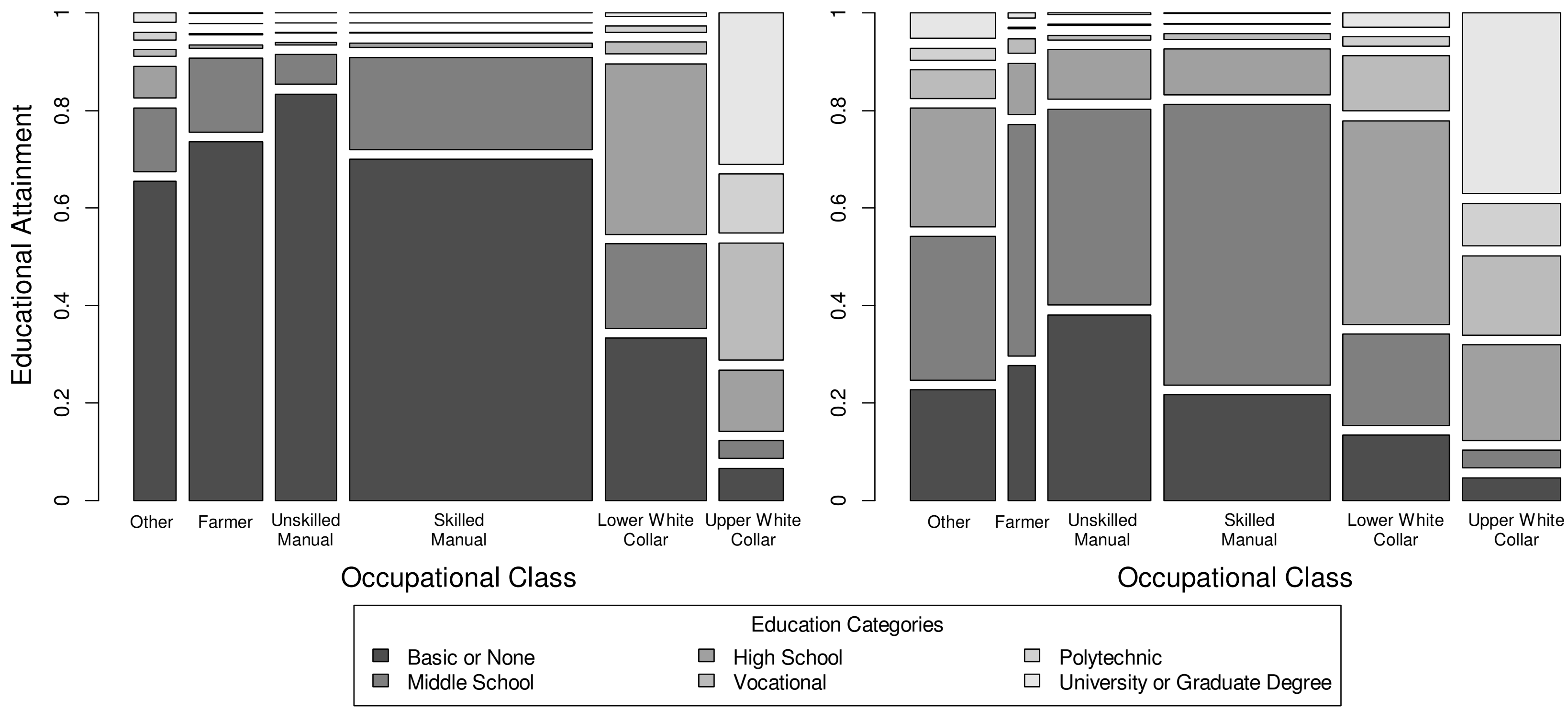
Source: Authors' calculations based on Finnish registry data and censuses.
Note: The darker and lighter colors represent lower and higher education categories, respectively. Years on x-axis indicate the end of a period. The education categorization changed for the 2001-2005 and later periods.

Figure 2. Changing Education Distribution by Age and Year, Females, Finland 1971-2010



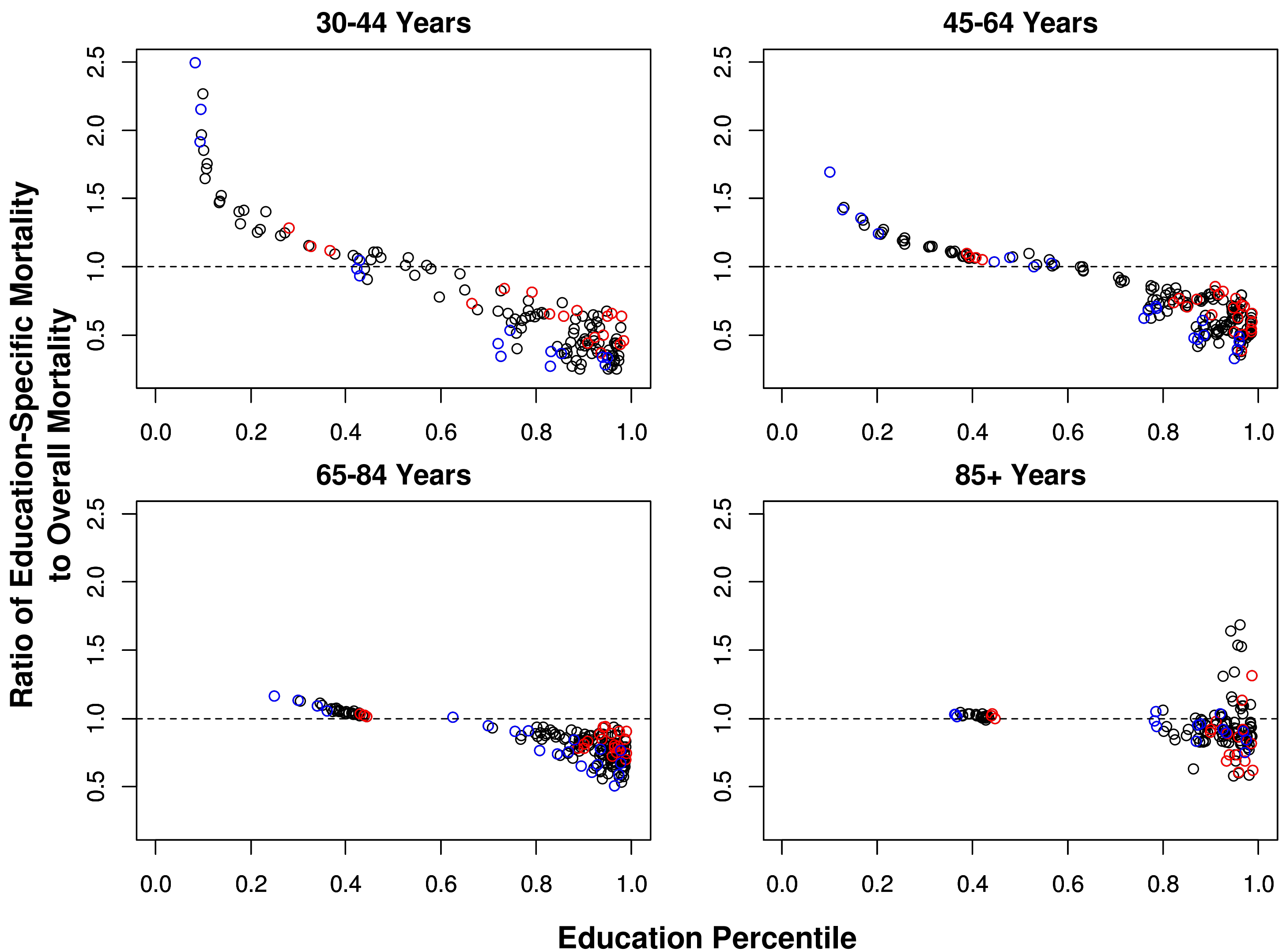
Source: Authors' calculations based on Finnish registry data and censuses.
Note: The darker and lighter colors represent lower and higher education categories, respectively. Years on x-axis indicate the end of a period. The education categorization changed for the 2001-2005 and later periods.

Figure 3. Education Distribution by Occupation Category, Males, Finland 1971-2000



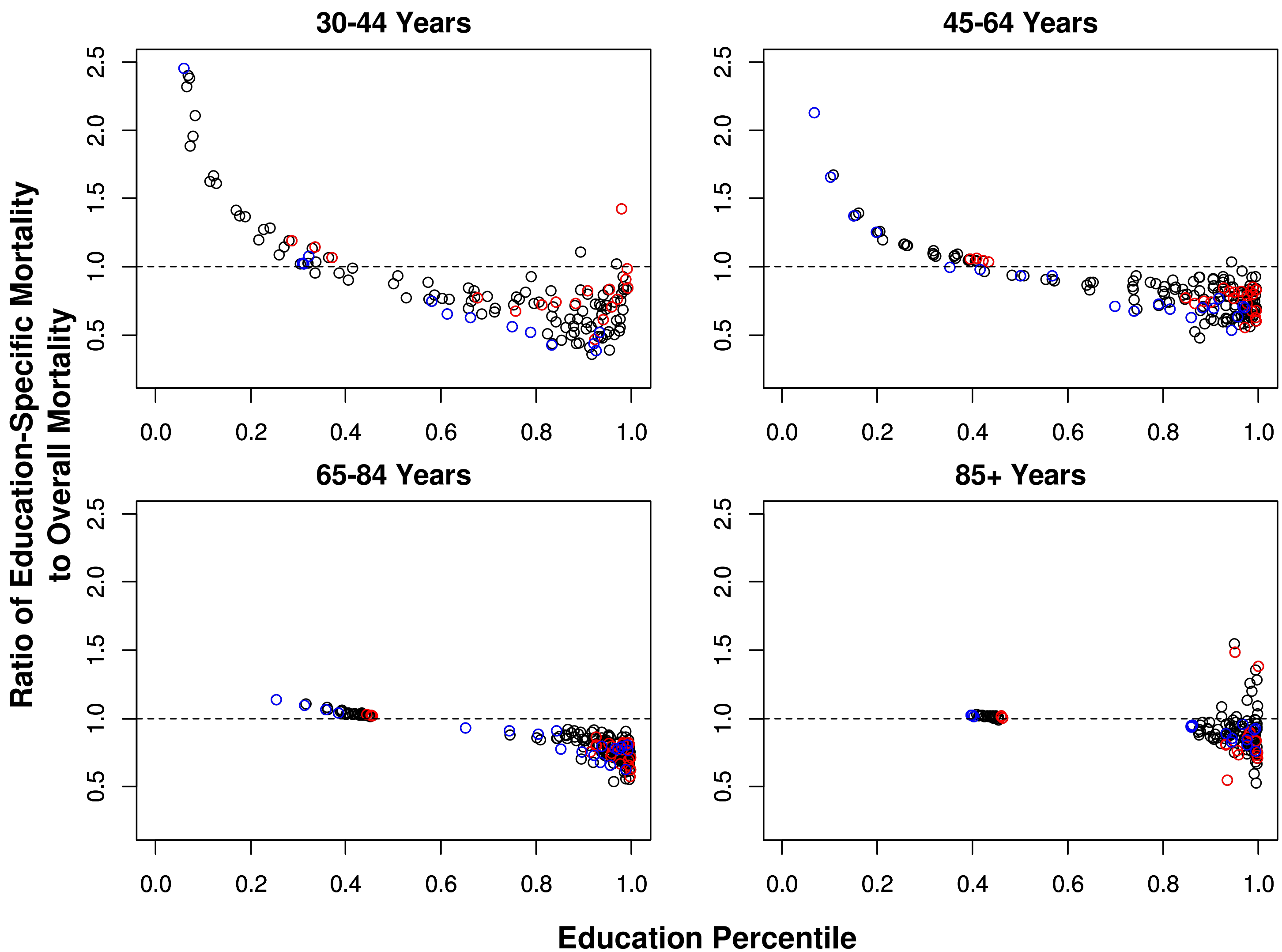
Source: Author's calculations based on Finnish censuses
Note: Lower occupation category numbers correspond to higher social class. The darker and lighter colors represent lower and higher education categories, respectively.

Figure 4. Ratio of Education-Specific Mortality to Overall Mortality by Age and Education Percentile, Males, Finland 1971-2010



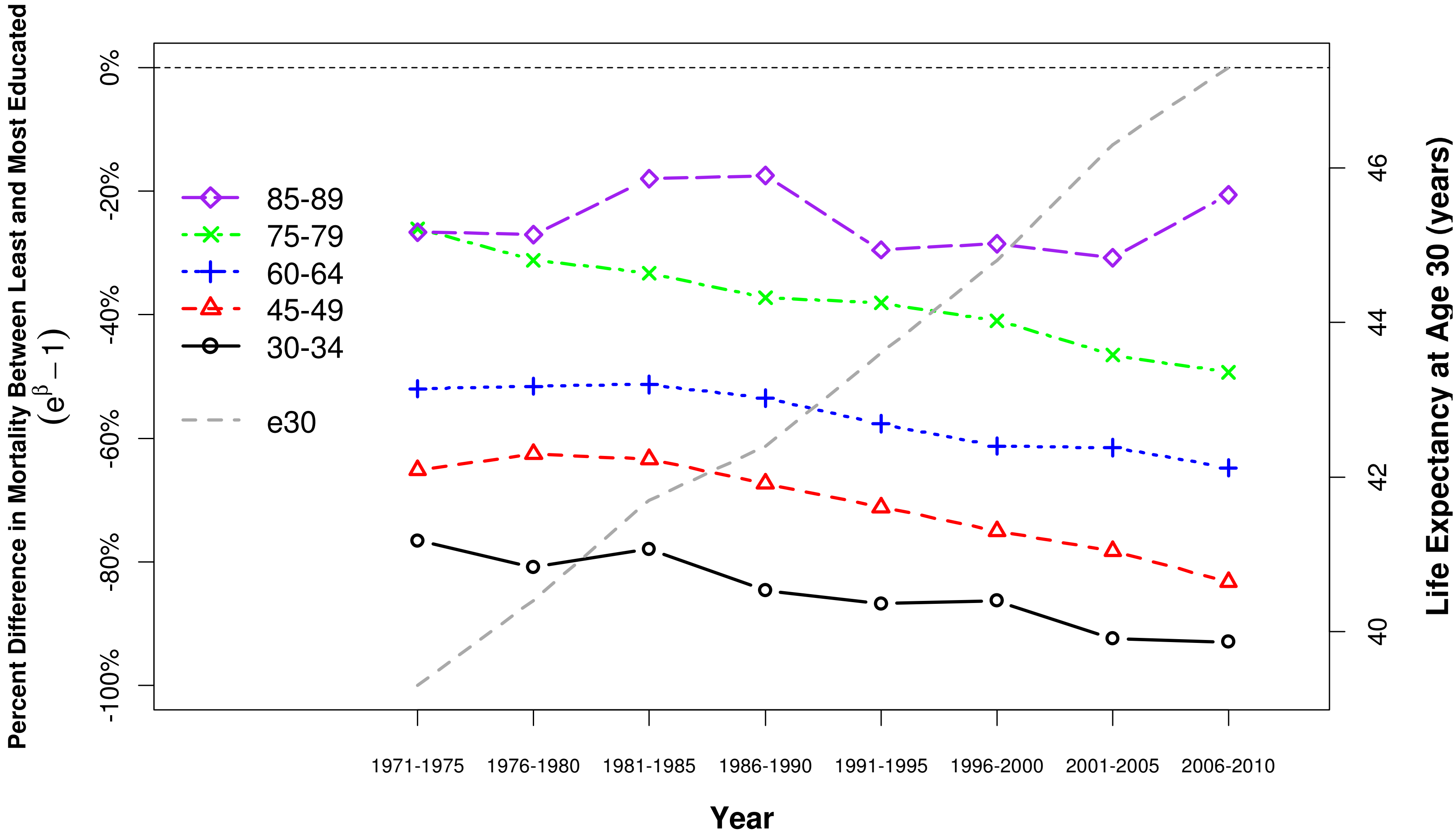
Source: Authors' calculations based on Finnish registry data and censuses.

Figure 5. Ratio of Education-Specific Mortality to Overall Mortality by Age and Education Percentile, Females, Finland 1971-2010



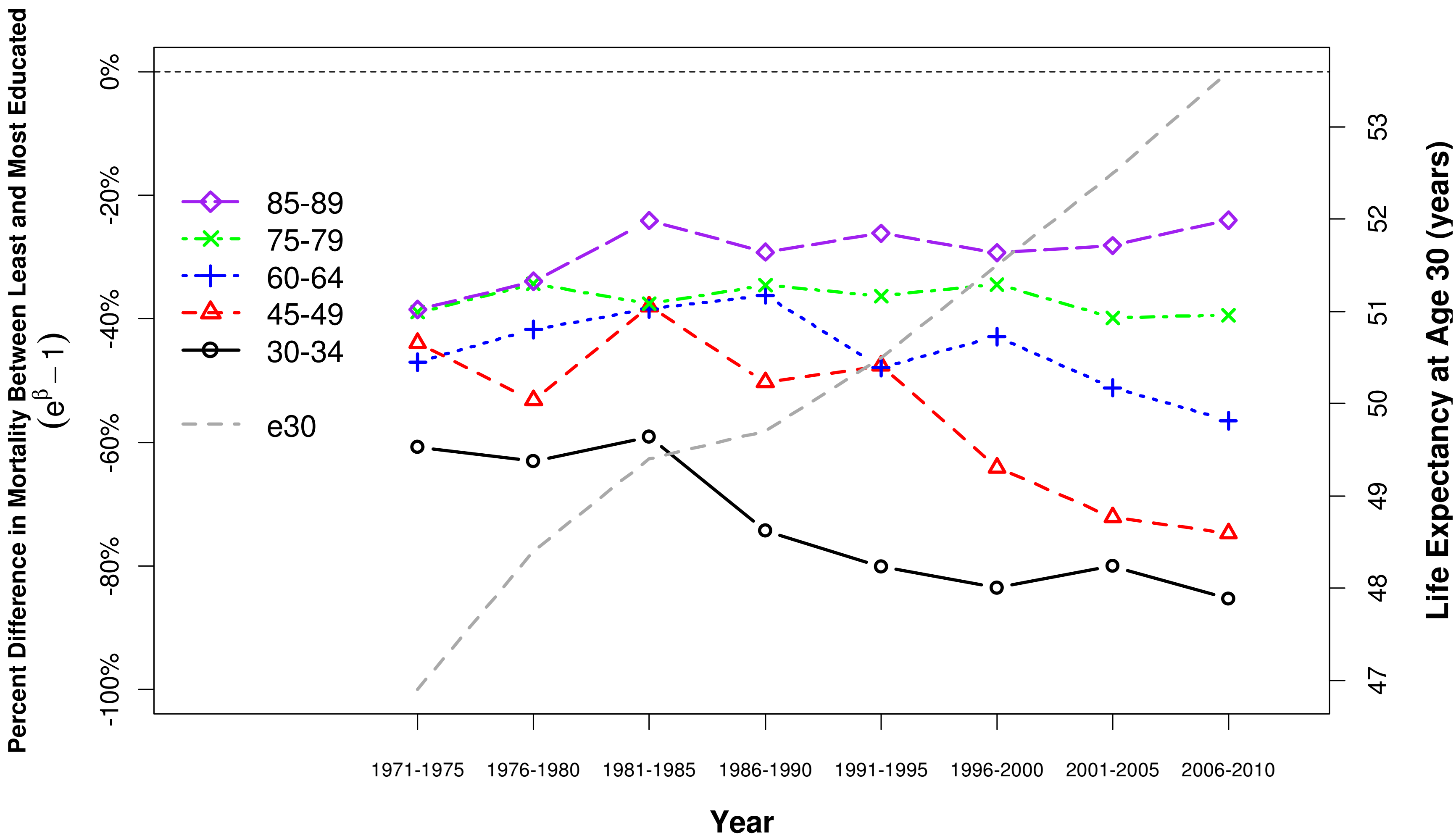
Source: Authors' calculations based on Finnish registry data and censuses.

Figure 6. Percent Difference in Mortality Between the Least and Most Educated by Age and Year, Males, Finland 1971-2010



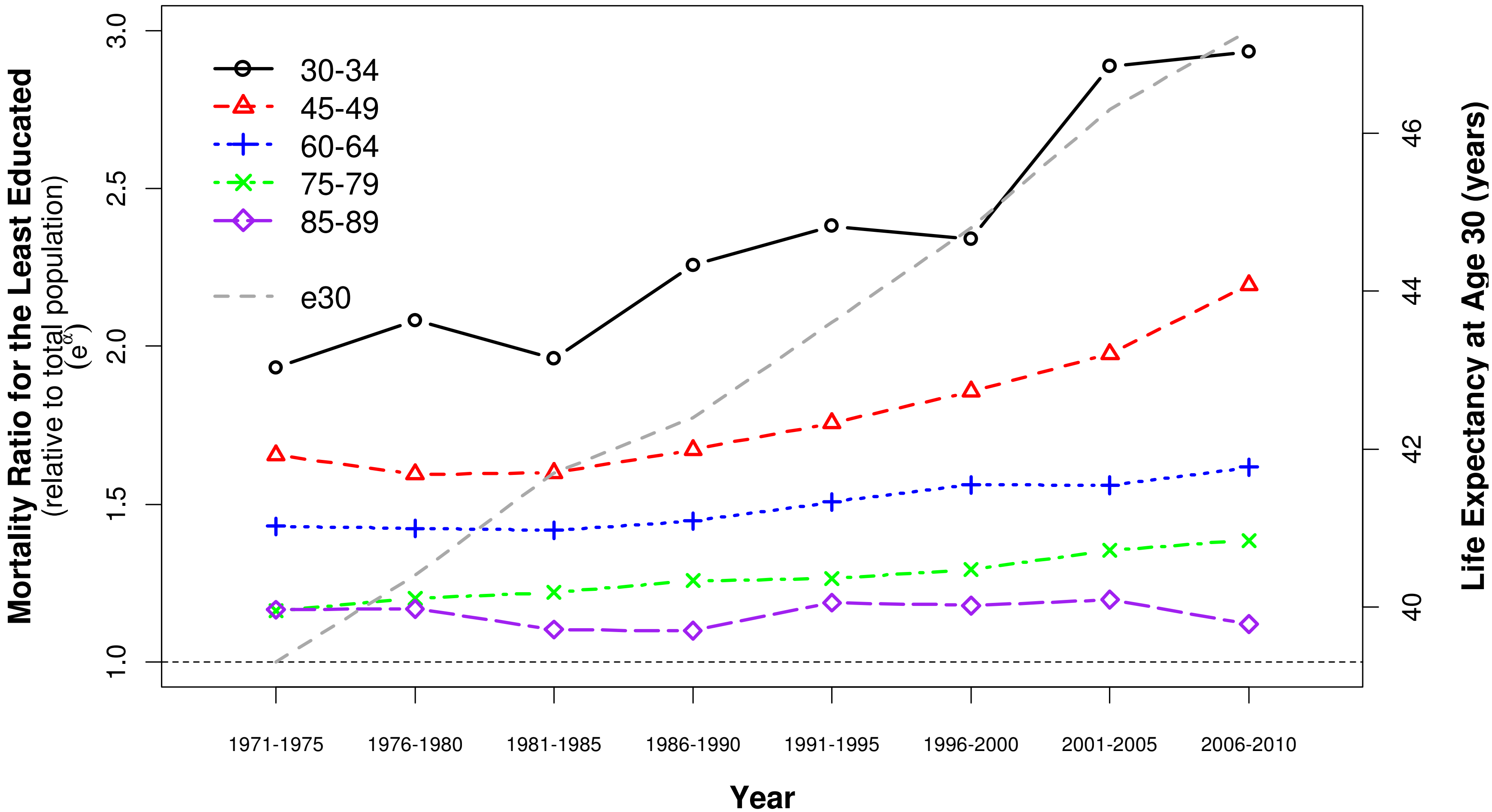
Source: Authors' calculations based on Finnish registry data and censuses.
Note: Values are estimated on the basis of regressions described in the text.

Figure 7. Percent Difference in Mortality Between the Least and Most Educated by Age and Year, Females, Finland 1971-2010



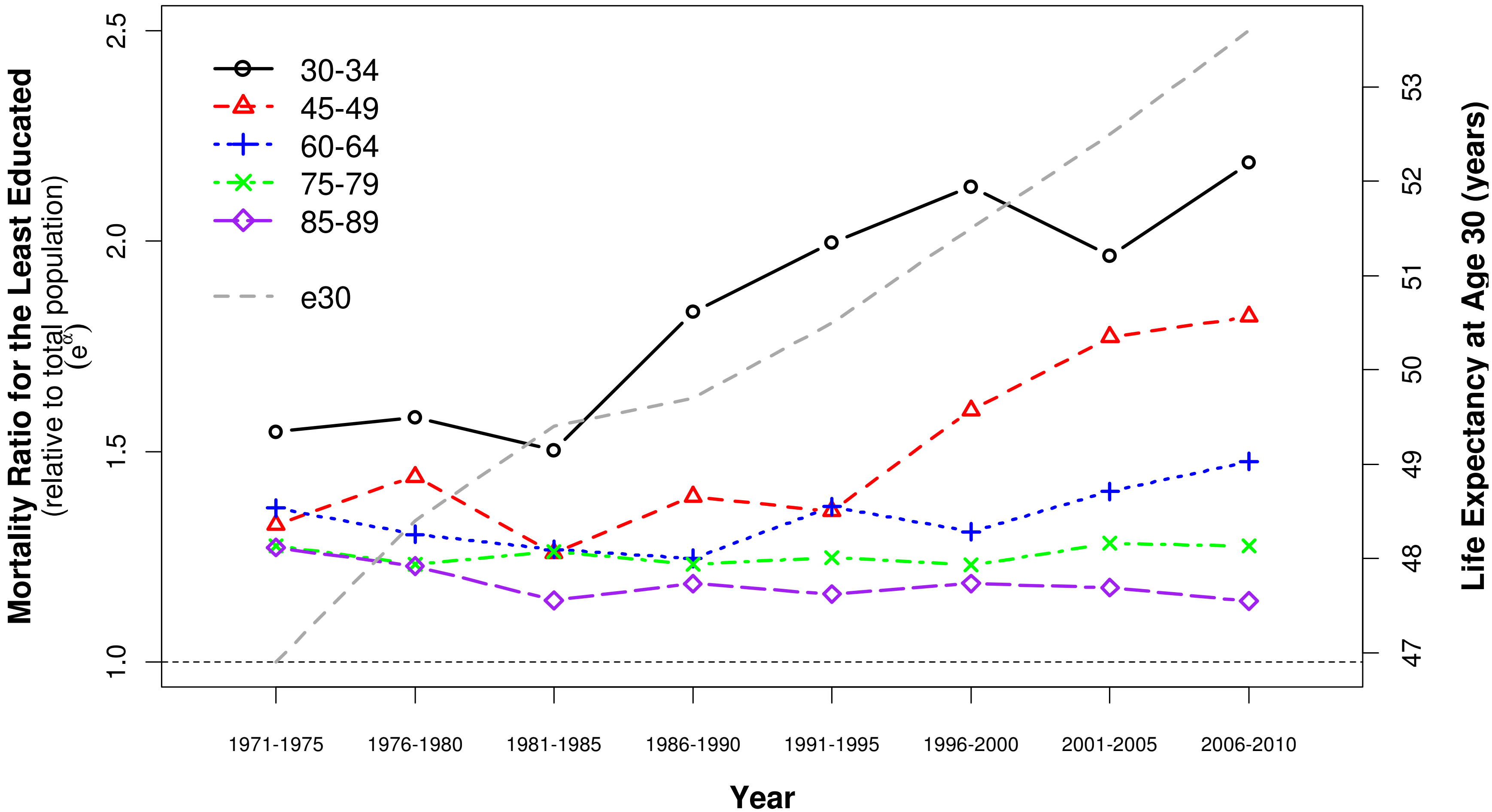
Source: Authors' calculations based on Finnish registry data and censuses.
Note: Values are estimated on the basis of regressions described in the text.

Figure 8. Ratio of Mortality among the Least Educated (0th percentile) to Overall Mortality by Age and Year, Males, Finland 1971-2010



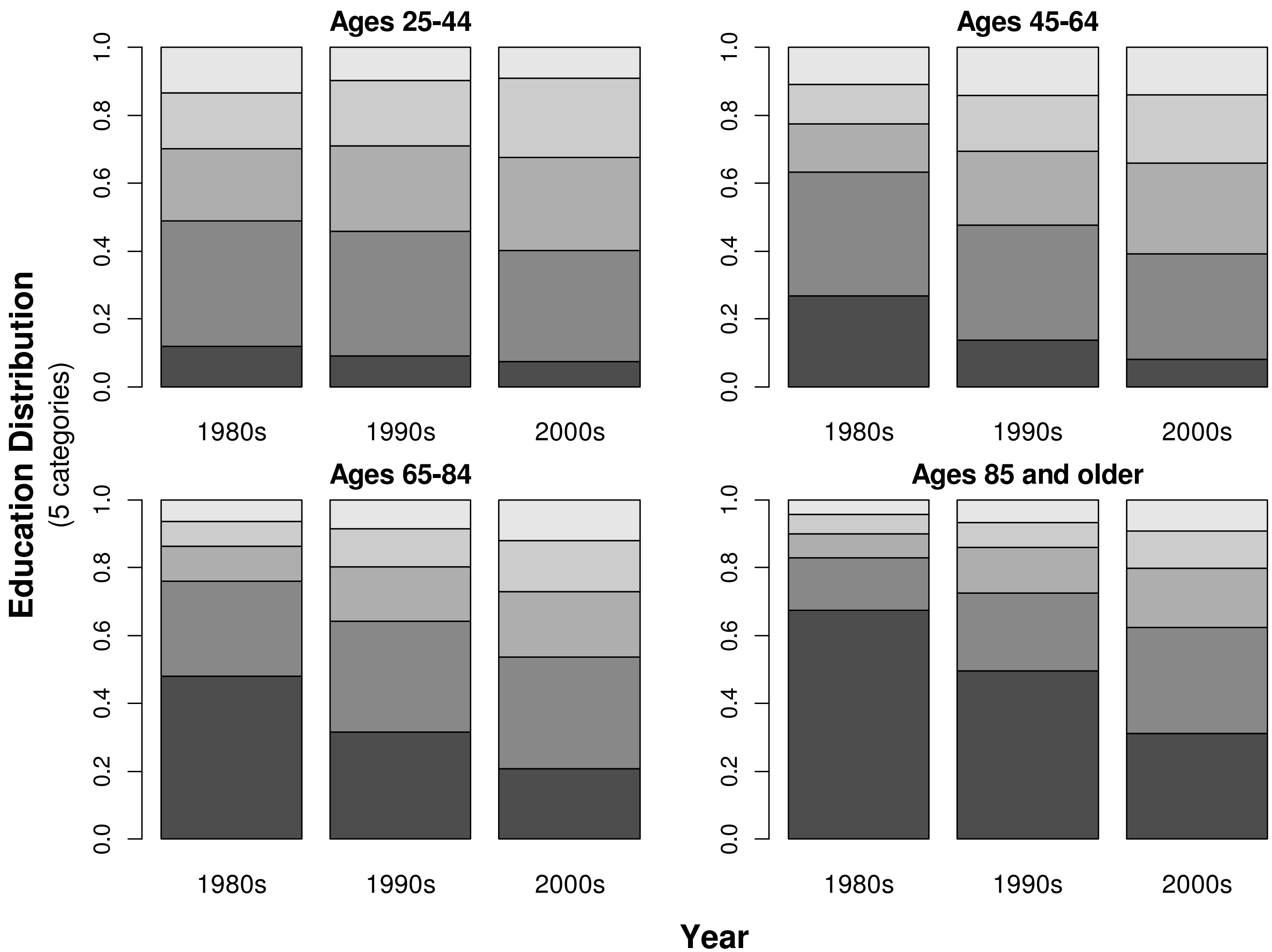
Source: Authors' calculations based on Finnish registry data and censuses.
Note: Values are estimated on the basis of regressions described in the text.

Figure 9. Ratio of Mortality among the Least Educated (0th percentile) to Overall Mortality by Age and Year, Females, Finland 1971-2010



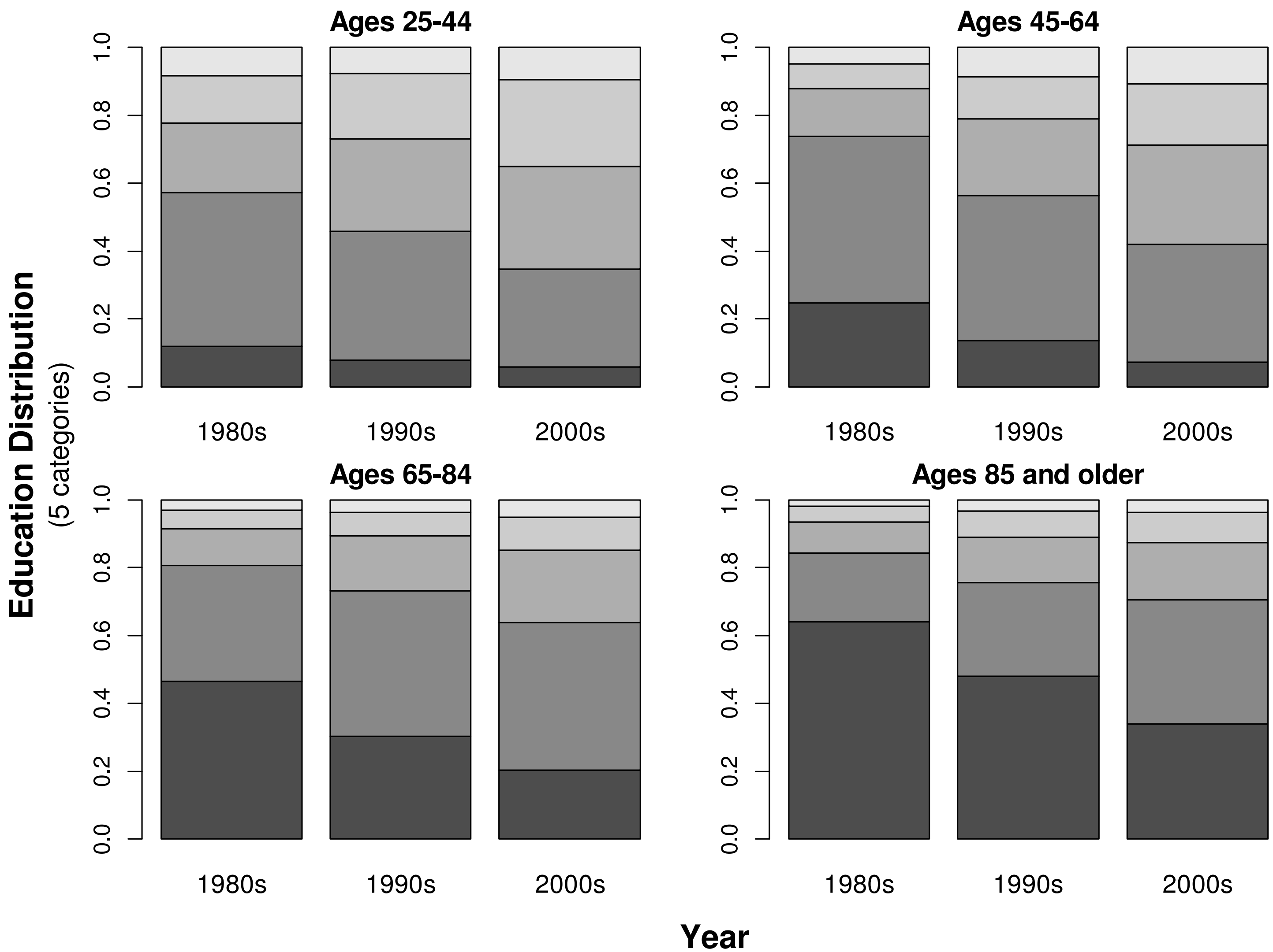
Source: Authors' calculations based on Finnish registry data and censuses.
Note: Values are estimated on the basis of regressions described in the text.

Figure 10. Education Distributions by Year and Broad Age Group, U.S. Non-Hispanic White Males, United States 1980s-2000s



Source: Authors' calculations based on NLMS Release 5

Figure 11. Education Distributions by Year and Broad Age Group, U.S. Non-Hispanic White Females, United States 1980s-2000s



Source: Authors' calculations based on NLMS Release 5

Table 1. Life Expectancy at Age 30 by Education and Year, Males and Females, Finland 1971-2010

Education Level	Time Period								Change Over Time
Males	***71-75***	***76-80***	***81-85***	***86-90***	***91-95***	***96-00***	***01-05***	***06-10***	***71-75 to 06-10***
1. Basic or None	38.6	39.5	40.7	41.1	42.0	43.0	43.9	44.4	5.7
2. Middle School	42.1	42.9	43.1	43.5	44.5	45.4	-	-	-
3. High School	41.5	42.8	44.1	44.8	46.1	47.4	46.8[a]	47.5[a]	-
4. Vocational	43.4	44.7	45.8	46.8	48.1	49.6	49.5	50.3	7.0
5. Polytechnic	43.2	43.3	45	45.8	47.4	49.1	50.7	51.8	8.6
6. University Degree[b]	43.7	45	46.2	47.6	48.9	50.3	51.4	52.7	9.0
Total	39.3	40.4	41.7	42.4	43.6	44.8	46.3	47.3	8.0
Difference (6-1)	5.1	5.5	5.4	6.5	6.9	7.3	7.5	8.3	3.3
Females	***71-75***	***76-80***	***81-85***	***86-90***	***91-95***	***96-00***	***01-05***	***06-10***	***71-75 to 06-10***
1. Basic or None	46.6	48.0	49.0	49.2	49.7	50.4	51.0	51.5	4.9
2. Middle School	49.2	50.1	50.8	51.0	51.7	52.5	-	-	-
3. High School	49.2	50.0	51.2	51.1	52.2	53.1	53.4[a]	54.2[a]	-
4. Vocational	49.3	50.9	51.8	52.2	53.2	54.4	54.6	55.8	6.5
5. Polytechnic	49.1	51.3	51.6	52.4	52.9	53.7	55.2	56.0	6.9
6. University Degree[b]	50.2	51.0	51.9	52.4	53.8	53.8	55.1	56.1	5.9
Total	46.9	48.4	49.4	49.7	50.5	51.5	52.5	53.6	6.7
Difference (6-1)	3.6	3.0	2.9	3.3	4.1	3.4	4.1	4.6	1.0

[a]Due to a change in Finland's educational system, the "High School" category from 2001 forward corresponds to the combined "Middle School" and "High School" categories in prior years.
[b]Includes people with university or graduate degrees.

Table 2. Life Expectancy at Age 30 by SES Quintile and Year, Males and Females, Finland 1971-2010

Education Level	Time Period								Change Over Time
Males	***71-75***	***76-80***	***81-85***	***86-90***	***91-95***	***96-00***	***01-05***	***06-10***	***71-75 to 06-10***
1. First Quintile	36.1	37.1	38.6	39.0	39.9	41.0	42.2	42.9	6.8
2. Second Quintile	37.9	38.9	40.3	40.9	42.0	43.2	44.6	45.6	7.7
3. Third Quintile	39.5	40.5	41.8	42.6	43.8	45.2	46.6	47.8	8.3
4. Fourth Quintile	41.0	42.1	43.3	44.1	45.5	46.9	48.4	49.6	8.6
5. Fifth Quintile	42.4	43.6	44.6	45.6	47.0	48.5	50.0	51.2	8.8
Total	39.3	40.4	41.7	42.4	43.6	44.8	46.3	47.3	8.0
Difference (5-1)	6.3	6.4	6.0	6.6	7.1	7.5	7.8	8.3	2.0
Females	***71-75***	***76-80***	***81-85***	***86-90***	***91-95***	***96-00***	***01-05***	***06-10***	***71-75 to 06-10***
1. First Quintile	44.7	46.5	47.6	47.9	48.6	49.5	50.3	51.4	6.6
2. Second Quintile	45.9	47.5	48.6	48.9	49.6	50.6	51.6	52.6	6.8
3. Third Quintile	47.0	48.5	49.4	49.8	50.6	51.6	52.7	53.8	6.8
4. Fourth Quintile	48.0	49.4	50.3	50.6	51.5	52.6	53.7	54.8	6.7
5. Fifth Quintile	49.1	50.3	51.1	51.4	52.4	53.4	54.6	55.7	6.6
Total	46.9	48.4	49.4	49.7	50.5	51.5	52.5	53.6	6.7
Difference (5-1)	4.3	3.8	3.5	3.5	3.8	3.9	4.3	4.3	0.0

Table 3. Counterfactual Life Expectancy at Age 30 by SES Quintile and Year Assuming No Change in Inequality, Males and Females, Finland 1971-2010

Education Level	Time Period								Change Over Time
Males	***71-75***	***76-80***	***81-85***	***86-90***	***91-95***	***96-00***	***01-05***	***06-10***	***71-75 to 06-10***
1. First Quintile	36.1	37.3	38.7	39.3	40.6	42.0	43.5	44.6	8.5
2. Second Quintile	37.9	39.0	40.3	41.0	42.2	43.5	45.0	46.0	8.2
3. Third Quintile	39.5	40.5	41.8	42.5	43.7	44.9	46.4	47.4	7.9
4. Fourth Quintile	41.0	42.0	43.2	43.9	45.0	46.3	47.6	48.7	7.7
5. Fifth Quintile	42.4	43.4	44.5	45.2	46.3	47.5	48.8	49.8	7.4
Total	39.3	40.4	41.7	42.4	43.6	44.8	46.3	47.3	8.0
Difference (5-1)	6.3	6.1	5.9	5.9	5.7	5.4	5.3	5.3	-1.0
Females	***71-75***	***76-80***	***81-85***	***86-90***	***91-95***	***96-00***	***01-05***	***06-10***	***71-75 to 06-10***
1. First Quintile	44.7	46.2	47.3	47.6	48.4	49.5	50.5	51.6	6.9
2. Second Quintile	45.9	47.4	48.4	48.7	49.5	50.5	51.6	52.6	6.8
3. Third Quintile	47.0	48.5	49.4	49.8	50.5	51.5	52.6	53.6	6.7
4. Fourth Quintile	48.0	49.5	50.5	50.8	51.6	52.5	53.5	54.6	6.6
5. Fifth Quintile	49.1	50.6	51.5	51.8	52.5	53.5	54.5	55.5	6.4
Total	46.9	48.4	49.4	49.7	50.5	51.5	52.5	53.6	6.7
Difference (5-1)	4.3	4.3	4.3	4.2	4.1	4.0	4.0	3.9	-0.4

Table 4. Life Expectancy at Age 25 by Year, Sex, and Education Category, Non-Hispanic Whites, United States 1980s-2000s

	Males				Females			
Education Level	Time Period			Change Over Time	Time Period			Change Over Time
	1980s	***1990s***	***2000s***	***1980s-2000s***	***1980s***	***1990s***	***2000s***	***1980s-2000s***
1. Less than High School	47.2	47.3	49.5	2.3	55.5	53.5	54.3	-1.2
2. High School	50.2	51.2	53.2	3.1	57.8	57.6	59.3	1.5
3. Some College	50.9	53.0	56.3	5.4	58.3	59.1	60.0	1.7
4. College	53.3	55.2	58.1	4.8	58.5	59.8	61.3	2.8
5. Postgraduate	54.8	55.7	60.7	5.9	59.4	60.9	63.4	4.0
Total	50.0	51.5	54.9	4.9	57.3	57.4	59.2	1.9
Difference (5-1)	7.6	8.4	11.2	3.6	3.9	7.3	9.1	5.2

Source: Authors' calculations based on NLMS Release 5.

Table 5. Life Expectancy at Age 25 by Year, Sex, and Education Quintile, Non-Hispanic Whites, United States 1980s-2000s

	Males				Females			
Education Level	Time Period			Change Over Time	Time Period			Change Over Time
	1980s	***1990s***	***2000s***	***1980s-2000s***	***1980s***	***1990s***	***2000s***	***1980s-2000s***
1. First Quintile	46.6	47.6	50.0	3.4	55.5	54.7	56.0	0.4
2. Second Quintile	48.6	49.9	53.0	4.4	56.5	56.3	57.9	1.4
3. Third Quintile	50.3	52.0	55.6	5.3	57.4	57.7	59.6	2.2
4. Fourth Quintile	51.9	53.9	57.8	5.9	58.2	59.0	61.1	2.9
5. Fifth Quintile	53.3	55.6	59.8	6.5	59.0	60.2	62.4	3.4
Total	50.0	51.5	54.9	4.9	57.3	57.4	59.2	1.9
Difference (5-1)	6.7	8.1	9.8	3.1	3.4	5.5	6.4	3.0

Source: Authors' calculations based on NLMS Release 5.

Table 6. Counterfactual Life Expectancy at Age 25 by Year, Sex, and Education Quintile Assuming No Change in Inequality Parameters, Non-Hispanic Whites, United States 1980s-2000s

	Males				Females			
Education Level	Time Period			Change Over Time	Time Period			Change Over Time
	1980s	***1990s***	***2000s***	***1980s-2000s***	***1980s***	***1990s***	***2000s***	***1980s-2000s***
1. First Quintile	46.6	48.2	51.8	5.1	55.5	55.8	57.6	2.1
2. Second Quintile	48.6	50.2	53.6	5.0	56.5	56.7	58.5	2.0
3. Third Quintile	50.3	51.9	55.2	4.9	57.4	57.6	59.3	1.9
4. Fourth Quintile	51.9	53.4	56.7	4.8	58.2	58.3	60.1	1.9
5. Fifth Quintile	53.3	54.7	57.9	4.6	59.0	59.0	60.8	1.8
Total	50.0	51.5	54.9	4.9	57.3	57.4	59.2	1.9
Difference (5-1)	6.7	6.5	6.2	-0.5	3.4	3.2	3.1	-0.3

Source: Authors' calculations based on NLMS Release 5.